DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

NOV 12 2002

FROM: AFCESA/CES
139 Barnes Drive, Suite 1
Tyndall AFB FL 32403-5319

SUBJECT: **Engineering Technical Letter 02-19: Airfield Pavement Evaluation Standards and Procedures**

1. Purpose. This ETL provides criteria and guidance for the structural evaluation of airfields using conventional evaluation methods. It supersedes guidance contained in Army Field Manual (FM) 5-430-1/Air Force Joint Pamphlet (AFJPAM) 32-8013, Vol. I, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations – Road Design*, and FM 5-430-00-2/AFJPAM 32-8013, Vol. II, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations - Airfield and Heliport Design*.

Note: The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

2. Application: All Air Force organizations responsible for evaluating airfields.

2.1. Authority: Air Force Policy Directive (AFPD) 32-10, *Air Force Installations and Facilities*.

2.2. Effective Date: Immediately. This ETL will remain in effect until these requirements are incorporated in FM 5-430-00-1/AFJPAM 32-8013V1 and FM 5-430-00-2/AFJPAM 32-8013VII.

2.3. Ultimate Recipients:

- Air Force Civil Engineer Support Agency (AFCESA) pavement evaluation teams
- Rapid Engineers Deployable Heavy Operations Repair Squadron Engineers (RED HORSE) units responsible for evaluating airfields
- Air Mobility Operations Groups (AMOG)
- Tanker Airlift Control Elements (TALCE)
- Contingency Response Groups (CRG)
- Special Tactics Teams (STT)

2.4. Coordination:

- Air Combat Command, Civil Engineer Operations Infrastructure Team (HQ ACC/CEOI), major command (MAJCOM) Pavement Engineer
- Air Mobility Command, Civil Engineer Operations Infrastructure Team (HQ AMC/CEOI), MAJCOM Pavement Engineer

- Air Mobility Command, Civil Engineering Readiness Operations (HQ AMC/CEXR) Pavement Evaluation Manager
- 615 AMOG Civil Engineer
- 23 Special Tactics Squadron (STS), Survey Section (representing 720 Special Tactics Group [STG])

3. References. See Attachment 1, page 67.

4. Acronyms and Terms. See Attachment 1, page 63, for a glossary of terms.

AC	- asphalt concrete
ACN	- aircraft classification number
ACP	- airfield cone penetrometer
ADCP	- automated dynamic cone penetrometer
AFJPAM	- Air Force Joint Pamphlet
AFJMAN	- Air Force Joint Manual
AFPD	- Air Force Policy Directive
AGL	- allowable gross load
AI	- airfield index
AMOG	- Air Mobility Operations Group
ASRR	- Airfield Suitability and Restrictions Report
ASTM	- American Society for Testing and Materials
CBR	- California Bearing Ratio
CRG	- Contingency Response Group
DBST	- double bituminous surface treatment
DCP	- dynamic cone penetrometer
DOD	- Department of Defense
ECP	- electronic cone penetrometer
ETL	- Engineering Technical Letter
FAIR	- Frost Area Index of Reaction
FASSI	- Frost Area Soil Support Index
FLIP	- Flight Information Publication
FM	- Field Manual
FOD	- foreign object damage
GDSS	- Global Decision Support System
GPS	- Global Positioning System
HQ ACC/CEOI	- Air Combat Command, Civil Engineer Operations Infrastructure Team
HQ AFCESA/CESC	- Air Force Civil Engineer Support Agency, Technical Support Directorate
HQ AMC/CEOI	- Air Mobility Command, Civil Engineer Operations Infrastructure Team
HQ AMC/CEXR	- Air Mobility Command, Civil Engineering Readiness Operations
HQ AMC/DOK	- Air Mobility Command, Directorate of Operations
HQ AMC/DOVS	- Air Mobility Command, Airfield Suitability Branch

ICAO	- International Civil Aviation Organization
in	- inch
kip	- kilopound
LCN	- load classification number
LL	- liquid limit
LZ	- landing zone
MAJCOM	- major command
NIMA	- National Imagery and Mapping Agency
OJT	- on-the-job training
OPR	- office of primary responsibility
PCASE	- Pavement-Transportation Computer Aided Structural Engineering
PCC	- Portland cement concrete
PCI	- Pavement Condition Index
PCN	- pavement classification number
PI	- plasticity index
PL	- plastic limit
PPD	- physical property data
psi	- pound per square inch
RED HORSE	- Rapid Engineers Deployable Heavy Operations Repair Squadron Engineers
RPCC	- reinforced Portland cement concrete
RRM	- rolling resistant material
SPACI	- Semi-Prepared Airfield Condition Index
STG	- Special Tactics Group
STS	- Special Tactics Squadron
STT	- Special Tactics Team
TALCE	- Tanker Airlift Control Element
UFC	- Unified Facilities Criteria
UNSURF	- Unsurfaced Design
USACE	- U.S. Army Corps of Engineers
USCS	- Unified Soil Classification System

5. Points of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to: HQ AFCESA/CESC, 139 Barnes Drive, Suite 1, Tyndall AFB, 32403-5319, Attention: Mr. Dick Smith, DSN 523-6084, commercial (850) 283-6084, e-mail richard.smith@tyndall.af.mil; or Mr. Jim Greene, DSN 523-6334, commercial (850) 283-6334, e-mail james.greene@tyndall.af.mil.

MICHAEL J. COOK, Colonel, USAF
Director of Technical Support

2 Atch
1. Airfield Pavement Evaluation, Standards and Procedures
2. Distribution List

AIRFIELD PAVEMENT EVALUATION

Standards and Procedures

October 2002

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY
139 BARNES DR, SUITE 1
TYNDALL AIR FORCE BASE, FLORIDA 32403-5319

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Introduction

This manual presents the basic criteria and procedures used to determine the structural suitability or load-bearing capability of an airfield to sustain aircraft operations using conventional evaluation procedures. Appropriate evaluation charts are included for the various fighter, transport, and tanker aircraft commonly used in Air Force operations. Charts will be added for additional aircraft as they become available. This manual does not address the geometric characteristics of an airfield such as runway length and width, gradient criteria, or airfield and airspace clearances. Geometric criteria for Department of Defense (DOD) military facilities are contained in Unified Facilities Criteria (UFC) 3-260-01, *Airfield and Heliport Planning and Design*. Contingency airfield geometric criteria is contained in FM 5-430-1/AFJPAM 32-8013, Vol. I, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations – Road Design*, FM 5-430-00-2/AFJPAM 32-8013, Vol. II, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations - Airfield and Heliport Design*, and ETL 98-5, *C-130 and C-17 Contingency and Training Airfield Dimensional Criteria*.

The HQ AFCESA Pavement Evaluation Team is tasked to assess the structural capability of airfields for projection of U.S. forces in support of regional conflicts or peacetime human relief operations. Other Air Force units such as RED HORSE squadrons, Air Mobility Operations Groups (AMOG), Tanker Airlift Control Elements (TALCE), Contingency Response Groups (CRG), and Special Tactics Teams (STT) are also tasked to perform airfield evaluations. These taskings have increased substantially in recent years and have highlighted the need to ensure those tasked are sufficiently trained and to standardize evaluation procedures.

The procedures presented here are those required to adequately evaluate an airfield. In cases where in-the-field evaluation time is limited and judgments must be made on limited available data, the reliability of the evaluation is questionable. Contact AFCESA before reporting airfield capability in such situations.

Those tasked to evaluate airfields must be adequately trained and certified. Initial classroom training in evaluation procedures and software will be conducted at HQ AFCESA. Subsequent on-the-job training (OJT) or home station training will be established by and conducted under the guidance of the MAJCOM pavement engineer. Upon completion of initial and home station training, the MAJCOM pavement engineer will submit the names to AFCESA for certification. Those certified should receive annual recurring training at AFCESA to retain certification, but this may not always be possible. The recurring training may have to be postponed, but it must be accomplished as soon as scheduling and mission requirements permit. A certification will be valid for a period not to exceed two years.

If questions arise in the field, contact one of the following:

- HQ AFCESA/CESC
  139 Barnes Drive, Suite 1
  Tyndall AFB, FL 32403-5319

Mr. Richard Smith (Primary)	DSN 523-6084	Comm (850) 283-6084
Mr. James Greene (Alternate)	DSN 523-6334	Comm (850) 283-6334
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- USACE ERDC Pavement System Division
  U S Army Engineer Waterways Experiment Station
  3909 Halls Ferry Road
  Vicksburg, MS 39180-6199

Mr. Don Alexander (Primary)	Comm (601) 634-2731 or 1-800-522-6937 ext 2731
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FAX	Comm (601) 634-3020

Structural evaluation of an airfield can be broken down into steps, as shown in Figure 1. Each of these steps is detailed in this manual.

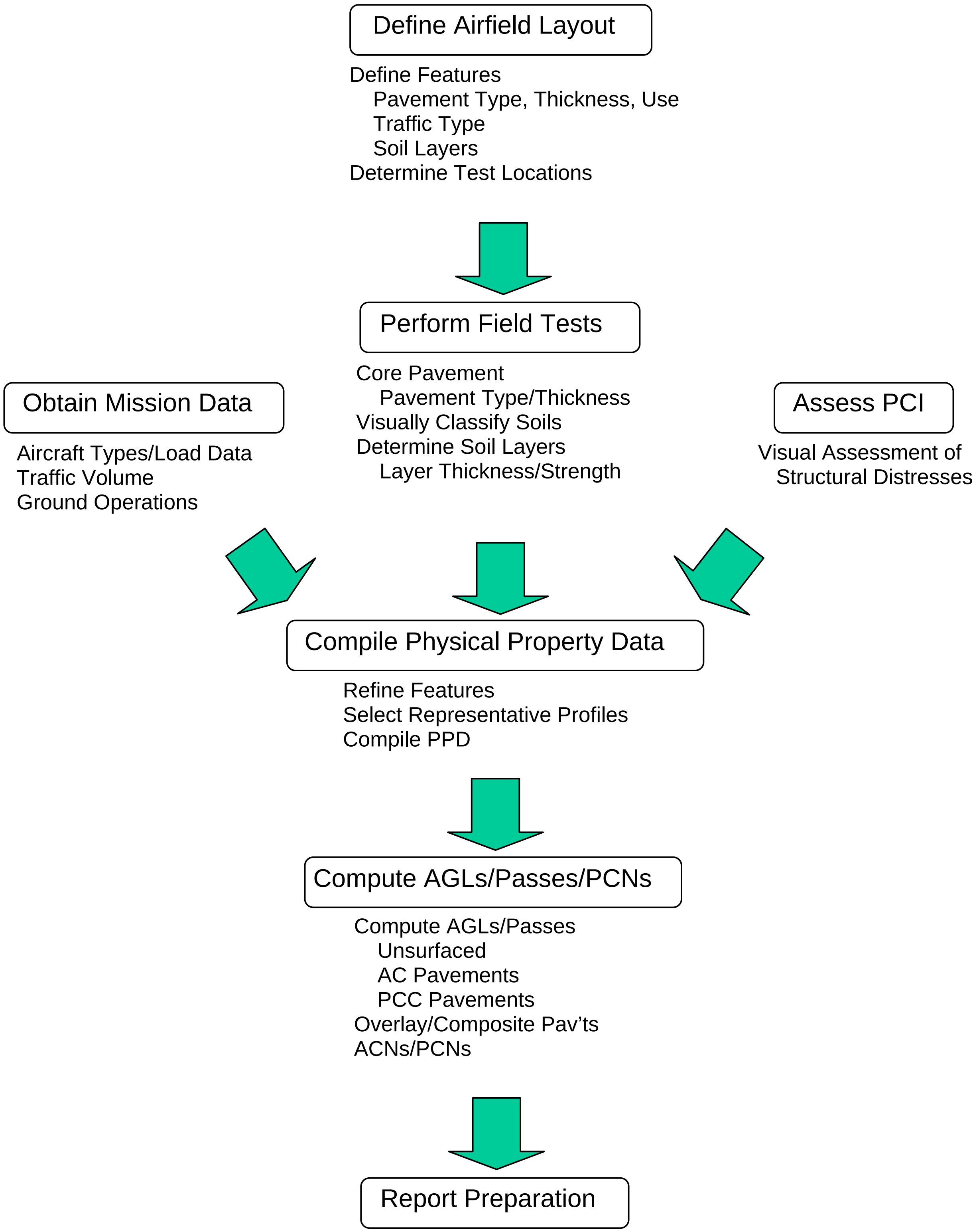


Figure 1. Evaluation Procedures

1. Define Initial Airfield Layout.

1.1. Make an initial tour of the airfield to:

- Identify operational surfaces and define the scope of the evaluation.
- Identify any limiting factors, such as areas with visual evidence of problems (e.g., drainage, high-severity distresses, major repairs) or areas unsuitable for operations due to geometrics.

1.1.1. Verify the dimensions of airfield pavements and accuracy of existing drawings, if available. Existing information on the airfield is helpful, such as: soil boring data; geological, topographical, and agricultural maps; and aerial photographs. Several unclassified sources are available that provide information on airfields.

- AFCESA/CESC, Pavements Laboratory, DSN 523-6084, commercial (850) 283-6084.
- AMC Global Decision Support System (GDSS) or Airfield Suitability and Restrictions Report (ASRR), HQ AMC DOVS, DSN 779-2677/3112, commercial (618) 229-2677/3112, https://www.afd.scott.af.mil
- Assault Zone Survey Repository, HQ AMC DOK, DSN 779-3148/3727, commercial (618) 229-3148/3727.
- DOD Flight Information Publications (FLIP), National Imagery and Mapping Agency (NIMA), DSN 693-4864, commercial 1-800-455-0899, http://www.nima.mil.
- Host nation data, if available.

1.1.2. If time is limited or if high-tech surveying equipment such as Total Station or Global Positioning System (GPS) is not available, use expedient methods to survey (taping, measuring wheel, or pacing).

1.1.3. Update existing plans or make new scaled drawings as required.

1.2. Divide the airfield pavement system into features based upon common characteristics: the pavement type, thickness, surface condition, and construction history data; available subsurface layer data; pavement use; and traffic type (see Figure 2).

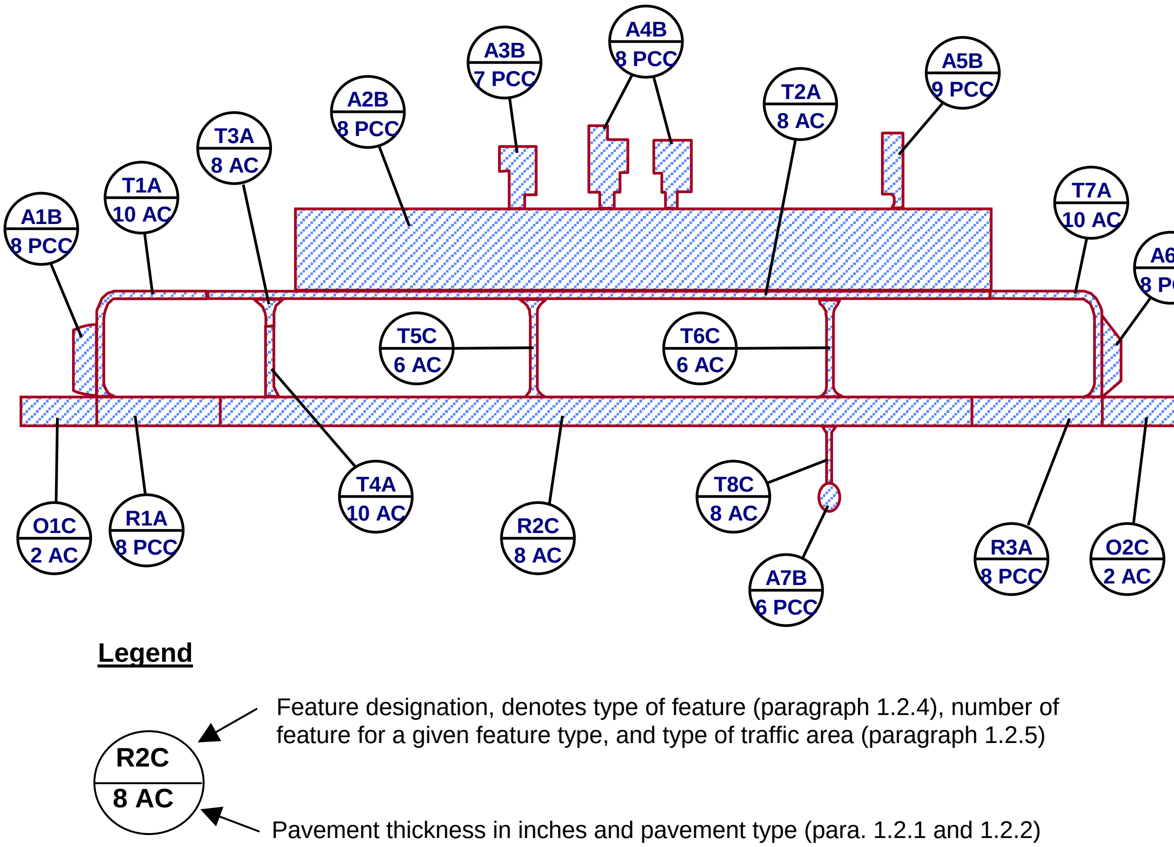


Figure 2. Airfield Layout/Feature Plan

1.2.1. Pavement Types. A specific feature contains only one pavement type.

- Flexible asphalt concrete (AC)
- Rigid Portland cement concrete (PCC)
- Flexible overlay on rigid base (AC over PCC)
- Rigid overlay on rigid base (PCC over PCC)
- Composite, rigid overlay on flexible overlay on rigid base (PCC over AC over PCC)
- Reinforced Portland cement concrete (RPCC)
- Double bituminous surface treatment (DBST)
- AM-2 Mat
- Semi-prepared (gravel/unsurfaced)
- Other overlay combinations

1.2.2. Pavement Thickness and Construction History Data. All pavement sections in a specific feature must share a constant nominal thickness, uniform surface type, and a common construction history. Construction history is comprised of data including the materials used and year of original construction, as well as all subsequent maintenance and repair materials and techniques.

1.2.3. Subsurface Layers:

- Types
- Thicknesses
- Strengths

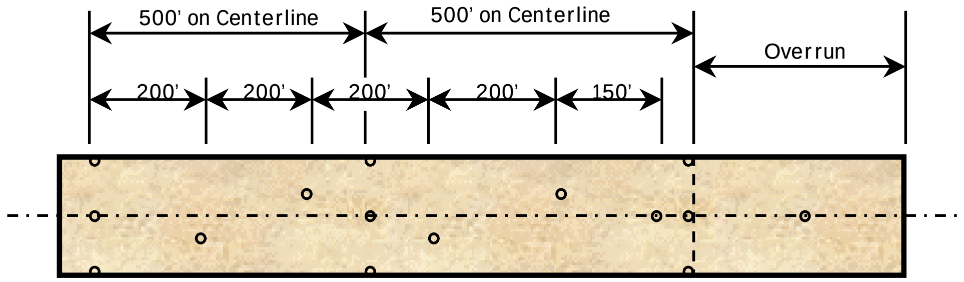
1.2.4. Pavement Use:

- R = Runway
- O = Overrun
- T = Taxiway
- A = Apron

1.2.5. Traffic Type. Traffic type is categorized by traffic area as a function of traffic distribution and aircraft weight.

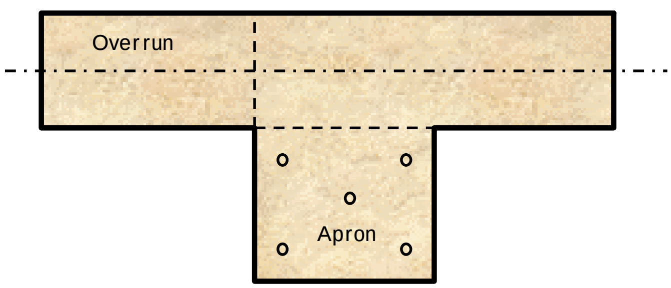
- **Type A Traffic Area.** Evaluate for channelized traffic and full design weight of aircraft.
  - First 1,000 feet at each end of the runway
  - Primary taxiways
  - Other sections of runway, if required for back-taxi operations
  - **All operational surfaces of semi-prepared or unsurfaced airfields**
  - **All operational surfaces during an expedient airfield pavement evaluation**
- **Type B Traffic Area.** Evaluate for nonchannelized traffic and full design weight of aircraft.
  - Aprons
- **Type C Traffic Area.** Evaluate for nonchannelized traffic and 75% of design weight of aircraft.
  - Center section of runway, if not required for back-taxi operations
  - Secondary taxiways
  - Overruns

1.3. Determine Test Locations. The numbers and locations of pavement cores, soil strength tests, and soil samples will vary with the type of airfield, size of airfield, proposed mission of the airfield, number of features, and time available for conducting the tests. Test locations must be chosen wisely and should accurately cover each feature or aspect of the airfield, yet may need to be minimized due to aircraft operations or time constraints. Soil conditions are extremely variable; therefore, **perform as many tests as time and circumstance will permit**. The strength range and uniformity of the area will control the number of tests required. **In all cases, it is advisable to test apparent weak areas first, since the weakest conditions often control the pavement evaluation**. Look for signs of potential weak soil conditions. Wet areas, discolored soil, or vegetation often indicate drainage problems and weakened soils. Animal burrows such as gopher, prairie dog, snake holes, and anthills may indicate subsurface air pockets or voids in the soil. Previously forested areas may also contain excessive subsurface roots and organic matter that decay and create an extremely weak soil structure. In areas of doubtful strength or where evidences of changing layer structure occur, the tests may be closely spaced. On the other hand, in areas where the structure appears to be firm and uniform, tests may be few and widely spaced. After weak areas have been tested, areas of high traffic intensity or loading such as take-off/touch-down zones, runway/taxiway intersections, and taxi lanes on aprons should be tested. Figures 3 and 4 show test locations for semi-prepared or aggregate surfaced airfields and Figures 5, 6, and 7 show test locations for AC- or PCC-surfaced airfields.



Note: For unimproved airfield, continue this pattern throughout the length. For aggregate surfaced airfields, the pattern may be more widely spaced on the remaining portion of the airfield.

Typical Semi-prepared Airfield

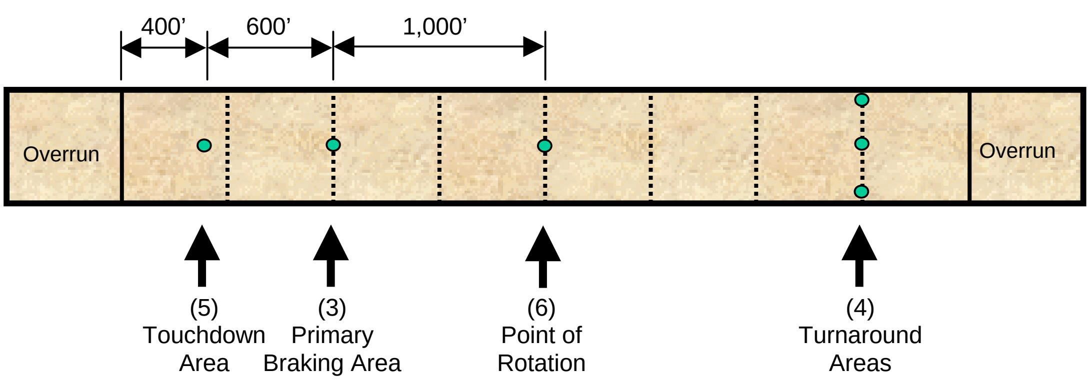


Typical Apron/Turnaround

<u>Priority Testing</u>

1. Soft spots
2. Offsets (should be in wheel paths of main gear)
3. Centerline
4. Aircraft turnarounds
5. Any area where the aircraft must stop
6. Overrun, one test in center (If overrun is used as a turnaround or for takeoffs, more tests are required)
7. Along edges at 500-foot intervals

Figure 3. Recommended Test Locations for Semi-prepared Airfields



(1) Identified Soft Spots / Wet Areas
(2) Repaired Areas

(7) LZ end 50 feet from threshold
(8) Offsets along LZ centerline

Note: Perform as many tests as time permits, but prioritize locations

Figure 4. Priority of Test Locations to Validate LZs when Testing is Limited Due to Time Constraints

Priority Testing

Soft spots/weak areas
Runway touchdown zone, minimum 2
Runway at taxiway intersections
Runway center feature, every 500 to 1,000 feet, minimum 2 per feature
Taxiways, every 1,000 feet, minimum 2 per feature
Aprons, minimum 3 per feature

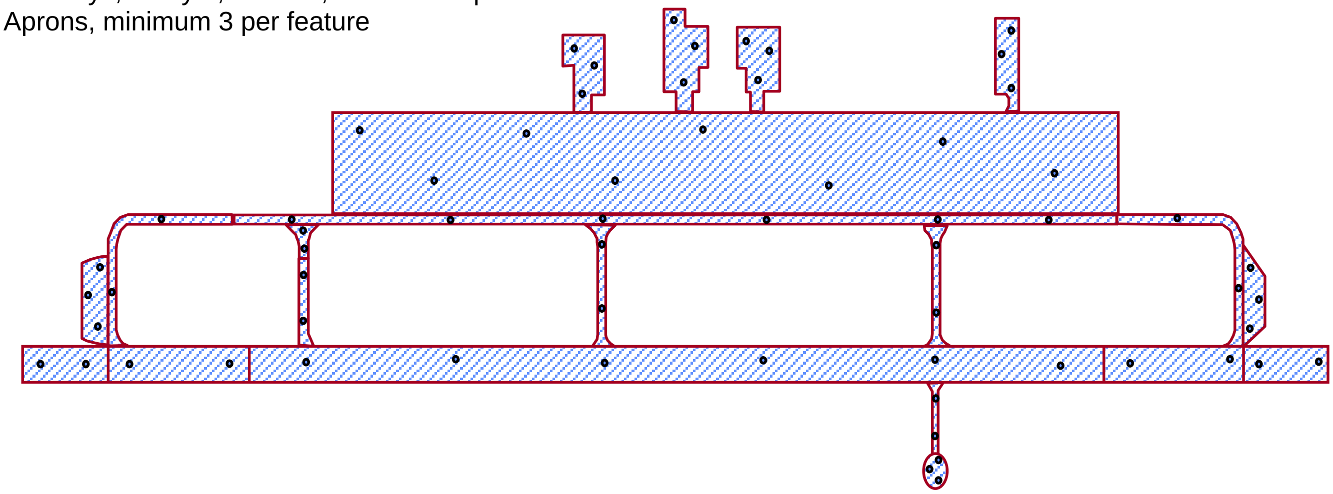


Figure 5. Recommended Test Locations for AC- and/or PCC-Surfaced Airfields, Permanent or Standard Evaluation

Note: Perform as many DCP tests as time permits, but prioritize test locations to ensure all critical areas are tested. Tests in the **touchdown, primary braking, and rotation** areas should be performed in the main gear paths. Tests at the **turnaround areas** should be conducted near the lateral edges of the operational surface as well as along the runway centerline.

(1) Identified soft spots/wet areas
(2) Repaired areas/crater repairs
(3) Weak features

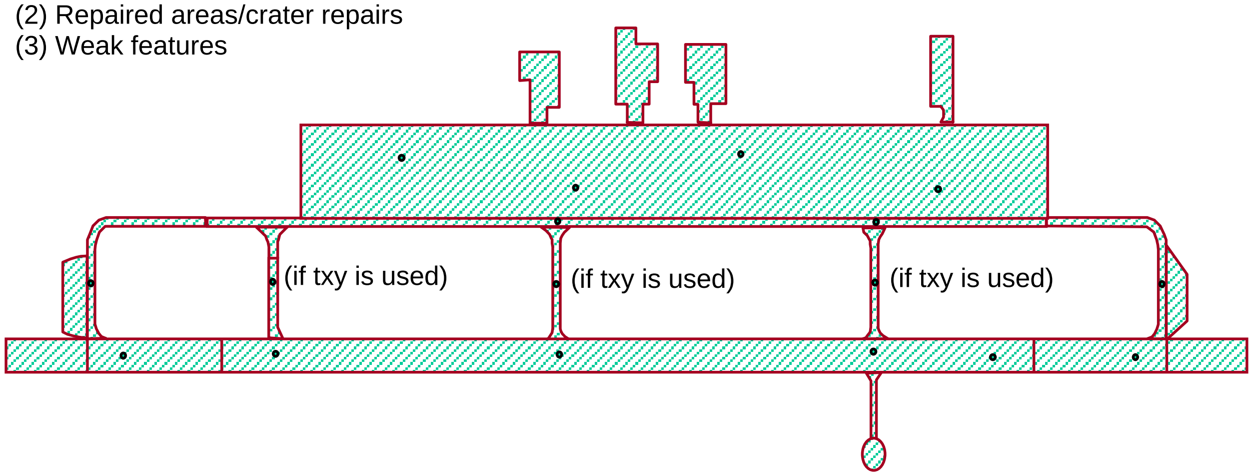


Figure 6. Minimum Test Locations for AC- and/or PCC-Surfaced Airfields, Sustainment Evaluation

Note: Perform as many DCP tests as time permits, but prioritize test locations to ensure all critical areas are tested.

<u>Minimum Test Locations (when no information is available)</u>

(1) Runway
- (a) Weak areas (e.g., identified soft spots or wet areas, repaired areas, crater repairs)
- (b) Threshold/touchdown areas
- (c) Aircraft turnarounds

(2) One test for each facility (taxiway or apron) required for operations

(3) Other weak areas

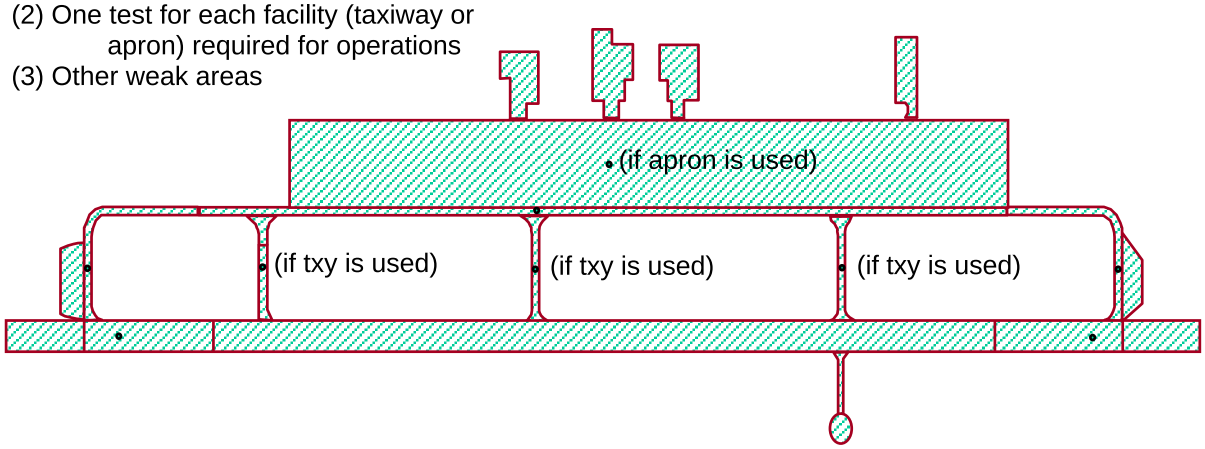


Figure 7. Minimum Test Locations for AC- and/or PCC-Surfaced Airfields, Expedient Evaluation

2. Collect Field Data to Determine Pavement Structural Properties.

2.1. Pavement. Visually identify the pavement types and measure thicknesses. When coring equipment is available, take cores in the wheel paths (see Table 1) to verify layers and thicknesses, and retain as needed for laboratory testing. **If coring in PCC, core in the center of the slab to avoid thickened edges**. If coring is not possible, then drill through the pavement to verify thickness and access subsurface layers. In cases where the host nation will not permit any disturbance of the pavement and no means are available to determine thickness in the traffic paths, assume thickness based on measurements taken at the pavement edge or construction history data.

Table 1. Wheel Path Offsets

Distance from Runway Centerline to Main Gear Centerline	Aircraft
4.5 feet	F-15, F-16, F-111, B-52
7 feet	C-130, B-1B
9 feet	F-4, C-141, A-10, 727, 737
11 feet	KC-135, E-3, 707
12.5 feet	C-17
18 feet	C-5, KC-10, 747

2.1.1. For evaluation of flexible pavements, no strength parameters are required for the flexible pavement surface layer. For evaluation of rigid (PCC) pavements, the flexural strength is required. If this data is not available, assign a strength based on:

- Type of aggregate in the mix and apparent bonding
- Visual assessment of pavement condition (severity of structural distresses)

Note: For stateside bases or other areas where quality control is good, use 700 pounds per square inch (psi). For other areas where quality control is uncertain, use 600 psi.

2.1.2. For expedient evaluation of rigid pavements, do not assume the existence of reinforcing if you do not see it. Evaluate it as plain PCC pavement.

2.2. Soil Layers.

2.2.1. Types.

- Identify base, subbase, and subgrade materials using field identification methods, and classify using the Unified Soil Classification System (USCS). See Appendix A.
- If field classification methods do not produce clear results or require validation, obtain samples for follow-up laboratory testing.
- Identify materials that have been altered or have additives as in the case of dense crushed rock layers or stabilized soil layers.

2.2.2. Thicknesses.

- Measure actual layer thicknesses through core holes as samples are collected

or

- Use dynamic cone penetrometer (DCP) data to determine layer thicknesses

Note: Be aware of other sources of strata information, such as ditches, excavations, or engineering documents—these provide useful information on the subbase/subgrade.

2.2.3. Strengths. Shearing resistance is one of the most important properties that a soil possesses. A soil's shearing resistance under given conditions is related to its ability to withstand a load. The shearing resistance is especially important in its relation to the supporting strength or bearing capacity of a soil used as a base or subgrade beneath airfield pavements.

2.2.3.1. For contingency pavement evaluations, the California Bearing Ratio (CBR) value of a soil is used as an empirical measure of soil strength. CBRs are used directly to evaluate unsurfaced and flexible (asphalt) pavement systems. CBRs are converted to K-values (modulus of soil reaction) to evaluate rigid (concrete) pavement systems. To determine the CBR, a dynamic load is applied to a piston whose end is 3 square inches in area, forcing it to penetrate the soil at a rate of 0.05 inch/minute. The psi load required to force penetration gives the modulus of shear that is converted to a CBR using established load factors. **The CBR value is expressed as a ratio in percent from 0 to 100. CBRs in excess of 100 will not be used.** Penetration into crushed, well-graded limestone serves as the benchmark material for CBRs—it has a CBR of 100. Laboratory methods for determining CBR values are time-consuming and thus impractical for expedient or contingency evaluations. Several methods are available to determine CBR values in the field:

2.2.3.1.1. Airfield Cone Penetrometer (ACP). The ACP is a probe-type instrument that when pushed down through the soil gives an airfield index (AI) of soil strength; these AIs are then correlated to CBR values. This instrument is commonly used by STTs for expedient evaluations because of its portability and simple operation. Its range is limited to 0 to 18 CBR and it will not penetrate many crusts, thin base course, or gravel materials. Consistency of test results is also difficult due to variability of soil strengths that impact the rate of penetration.

2.2.3.1.2. DCP*.* The DCP is the preferred method of obtaining CBR field data. It will measure soil strengths ranging from 1 to 100 CBR. It is a powerful, relatively compact, sturdy device that produces consistent results. See paragraph 2.2.3.3.

2.2.3.1.3. Automated Dynamic Cone Penetrometer (ADCP). Several automated versions of the DCP exist. These range from portable ADCPs that require manual lifting of the DCP weight coupled with automated data collection, to those that are truck-mounted and provide automated DCP operation and automated data collection along with coring capability. The data is analyzed in the same manner as the manual DCP data.

2.2.3.1.4. Electronic Cone Penetrometer (ECP). The contingency soils van operated by HQ AFCESA is equipped with an ECP that is hydraulically pushed through the soil layers to depths of typically 5 to 7 feet. The cone tip and sleeve pressures are measured and recorded by the on-board computer system and correlated to CBR values. These measurements also provide the friction ratio which is used in conjunction with the tip pressure to assist in soil classification. This one-of-a-kind item is also equipped with a core drill capable of coring through flexible and rigid pavement layers, is air-transportable by C-130, C-141, C-5, and C-17 aircraft, and provides accurate, consistent data. This van is neither available nor appropriate for all contingency evaluations, but its use should be considered when other methods of data collection do not provide clear results.

2.2.3.1.5. Small Aperture CBR Test. Standard CBR tests may also be performed through core holes in the pavement surface. This use is normally limited to tests on the surface of the base course. These tests may be performed in conjunction with DCP tests to validate the data, or as stand-alone tests in cases where use of the DCP is not applicable. These tests are described in detail in FM 5-472/NAVFAC MO 330/AFJMAN 32-1221(I), *Materials Testing*.

2.2.3.1.6. USCS Correlation*.* This is the quickest, yet least-accurate, method of determining CBR values. For each soil type, empirical studies have determined a range of CBR values. These values are shown on the Soil Characteristics Charts in Appendix A (Tables

A-2 and A-3). These CBR ranges are only estimates; due to the varying soil types and strengths encountered across an airfield, the lowest CBR values in the range should be used.

2.2.3.2. Measure soil layer thicknesses and strengths using the ACP.

2.2.3.2.1. Description. The ACP is a 0.375-inch-diameter rod with a cone attached to one end and a handle/load indicator on the other (see Figure 8). The angle of the cone is 30 degrees and the diameter of the base of the cone is 0.5 inch. For C-130 operations, two 12.625-inch long rods, graduated in 2-inch increments, are assembled to facilitate measuring soil strengths to a depth of 24 inches.

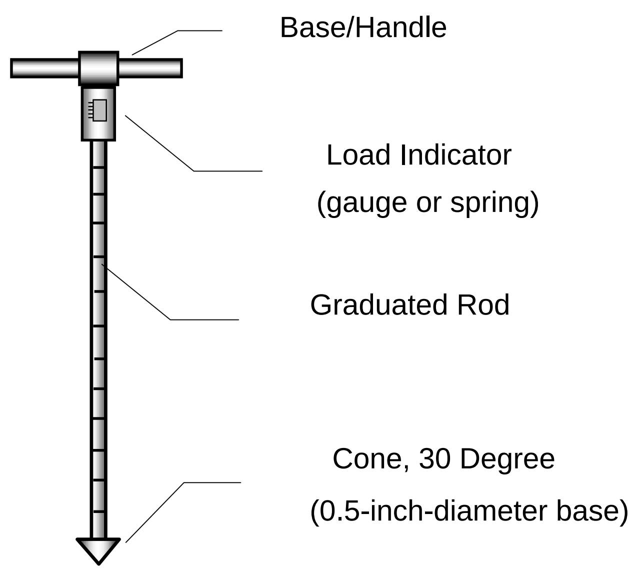


Figure 8. ACP

2.2.3.2.2. **Operation.** The ACP is placed in a vertical position and a downward force is slowly applied to the handle to ensure penetration into the soil at a rate of 0.5 to 1 inch per second. Readings should be taken at each 2-inch increment during penetration. **The test should be continued to a depth of 24 inches.** Because soil is not consistent and maintaining the proper rate of penetration is difficult, five penetrations should be taken using an X configuration at each test location, as shown in Figure 9, and recorded on a form similar to the one in Figure 10. Calculate the average of these readings to determine the AI with depth at each test location. These AIs can then be correlated to CBR values using Figure 11.

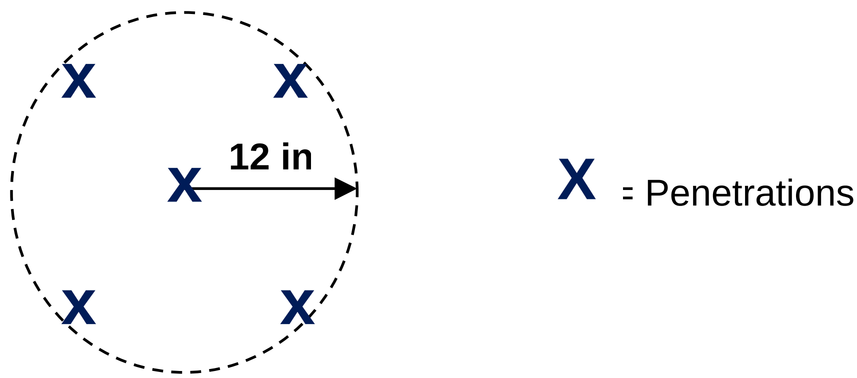


Figure 9. Layout of Penetrations per ACP Test Location

Location:							
Depth	Airfield Index					Sum	Avg
0	--	--	--	--	--	--	--
2	3	3	2	2	3	13	3
4	4	4	3	4	3	18	4
6	4	5	4	5	4	22	4
8	5	5	5	7	4	26	5
10	6	6	6	7	5	30	6
12	6	6	7	7	5	31	6
14	6	7	8	8	5	34	7
16	7	8	9	10	6	40	8
18	8	8	10	11	7	44	9
20	9	9	11	12	8	49	10
22	10	11	12	13	10	56	11
24	12	13	13	13	11	62	12
Comments:							

Figure 10. Recording and Averaging ACP Data

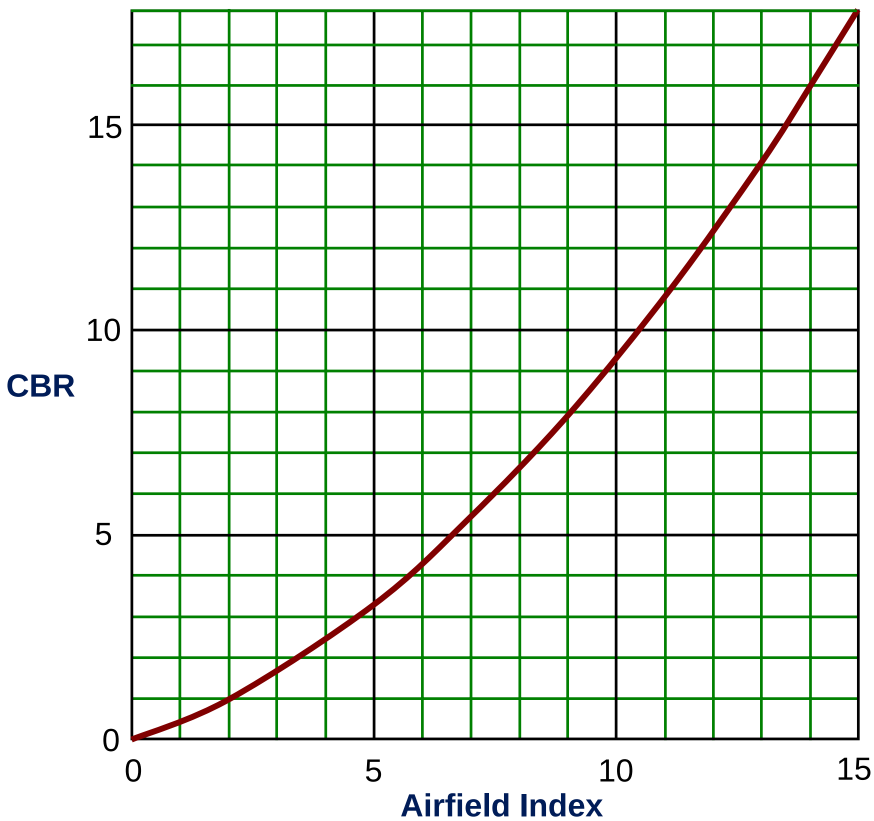


Figure 11. AI Correlation to CBR

2.2.3.2.3. Special Considerations.

2.2.3.2.3.1. The ACP works best in weak, fine-grained soils, such as silt and clay. It is not suitable for coarse-grained soils, such as gravels. **If it will not penetrate through stronger soil layers, do not assume that the soil strength underneath the impenetrable layer is adequate.**

2.2.3.2.3.2. If high-strength materials prevent penetration, the ACP should be removed from the hole and an auger drill should be used to remove the material to a point 2 inches below the depth where penetration ceased. The ACP test is then resumed and a CBR is assigned to the impenetrable layer. This ACP/auger procedure should be continued in 2-inch increments through the depth of the impenetrable layer or to a total depth of 24 inches beneath the surface for C-130 operations, or 36 inches for C-17 operations. This ensures that any soft subsurface soil layers are identified.

2.2.3.2.3.3. CBR values for impenetrable materials must be carefully selected. **If the impenetrable layer is subsurface or not identifiable, CBR 20 should be assigned.** If the impenetrable layer is on the surface or can be identified, the following CBR values may be used:

- Graded crushed aggregate 100
- Limerock 80
- Stabilized aggregate 80
- Soil cement 80

- Sand/shell or shell 80
- Gravel, with minimal (< 10%) fines 40
- Gravel, with >10% silts and/or clays 25
- Sand, with minimal (< 10%) fines 20

2.2.3.2.3.4. Soil behavior where coarse sands and gravels are involved is greatly dependent on the relative quantities of coarser particles and plastic fines. The presence of cobbles in the soil, which might prevent use of the ACP, does not in itself indicate a strong soil. If there are sufficient fines to overfill the voids between the cobbles, these cobbles are separated and no longer in contact. This soil would act much like a fine-grained soil. If, however, the fines are limited and do not overfill the voids between the coarse particles, the soil structure should be relatively stable.

2.2.3.2.3.5. Depth tests of 24 inches are usually adequate for C-130 operations, but soils are influenced to greater depths by heavier aircraft. If weak areas are suspected to exist at levels deeper than 24 inches, then tests should be continued deep enough to identify them.

2.2.3.3. Measure soil layer thickness and strengths using the DCP.

2.2.3.3.1. Description. The DCP consists of a stainless steel rod, 16 millimeters in diameter, with a cone attached to one end. The cone is driven into the soil by an 8 kilogram (17.6-pound) sliding hammer dropped from a height of 575 millimeters. The angle of the cone is 60 degrees and the diameter of the base of the cone is 20 millimeters. The rod may either be a scored version or smooth, requiring the use of an adjacent measuring scale (see Figure 12). Units that test both paved and semi-prepared airfields should use 50-inch long rods, but 36-inch long rods are available and adequate for semi-prepared airfield evaluations. Disposable cones that mount on an adapter may be used in cases where the cone is difficult to remove from the soil. This disposable cone remains in the soil. Use of disposable cones will increase the number of tests per day that can be accomplished.

Figure 12. DCP

2.2.3.3.2. Operation. Two people are required to operate the DCP. One person, the operator, holds the device by its handle in a vertical position and taps the device using the slide hammer until the base of the cone is flush with the surface of the soil. The second person, or recorder, then measures the distance between the cone and the surface to establish a baseline reading. The operator then raises and releases the hammer. **The hammer must be raised to the point of touching the bottom of the handle but not lifting the rod and cone. The hammer must be allowed to drop freely with its downward movement—not influenced by any hand movement. The operator must be careful not to exert any downward force on the handle after dropping the hammer.** The recorder ensures the device remains in a vertical position, measures the cone penetration, counts the number of hammer drops between measurements, and records the data. The number of blows or hammer drops between measurements is based on the rate of penetration. **The cone should penetrate at least 25 millimeters (1 inch) between measurements.** Both the operator and recorder should be alert to any sudden increases in cone penetration rates, which indicate weaker soil layers. A measurement should be recorded at that point to indicate the beginning of that layer. After the DCP has been driven to the desired depth, it should be extracted from the soil by bumping the drop hammer against the handle. The hammer must be raised in a vertical direction (rather than in an arching motion) or the rod may be bent or broken where it connects to the anvil. In some soils with large aggregate the DCP may try to penetrate the soil at a slant rather than from a true vertical direction. The operator should not apply force to the handle in an attempt to force vertical penetration—this may break the rod or connections**. Instead, the test should be stopped if the handle deviates from plumb more than 6 inches or comes in contact with the edge of the pavement, and a new test should be attempted in close proximity to the failed test.**

2.2.3.3.2.1. Maintenance of Equipment. The DCP should be kept clean and all soil should be removed before each test. Graphite, spray lubricant, or oil should be applied to the hammer slide before use each day. All joints should be constantly monitored and kept tight (Loc-Tite may be used). The lower rod should be kept clean and lubricated when clayey soils are tested.

2.2.3.3.2.2. Recording Data. A suggested format for DCP data collection is shown in Figure 13. The number of blows and penetration depths must be recorded during the test. Depending on the scale used, the depth of penetration readings is measured and recorded to the nearest 5 millimeters (0.2 inch).

DCP DATA SHEET							
BASE:		FEATURE:			DATE:		
TEST#:		TEST LOCATION:					
No of Blows (1)	Accum. Penetration mm (2)	Penetration p/Blow Set mm (3)	Penetration per Blow mm (4)	Hammer Blow Factor (5)	DCP Index (6)	CBR % (7)	Depth in. (8)

How to determine CBR

(1) No. of hammer blows between test readings

(2) Accumulative cone penetration after each set of hammer blows

(3) Difference in accumulative penetration (2) at start and end of each hammer blow set

(4) (3) divided by (1)

(5) Enter 1 for 17.6 lb hammer, 2 for 10.1 lb hammer

(6) (4) x (5)

(7) From CBR versus DCP correlation (Table 2 or 3)

(8) Divide (2) by 25.4, then round off to 0.2 inch

Figure 13. DCP Data Collection Sheet

2.2.3.3.3. Surface Layer Strengths. Lack of confinement at the top of the surface layer affects the DCP measurements. The penetration depth required to measure the surface layer strength accurately is related to the gradation and plasticity characteristics of the materials. The DCP can measure strengths of thin surface layers of fine-grained plastic materials but requires thicker surface layers for the non-plastic coarse-grained materials. The penetration depth required for measuring actual strength of the surface layer with the DCP for various soil types is shown in Table 2.

Table 2. Depth Required to Measure Surface Layer Strength

Soil Type	Average Penetration Depth
CH	1 inch
CL	3 inches
SC	4 inches
SW-SM	4 inches
SM	5 inches
GP	5 inches
SP	11 inches

2.2.3.3.4. Depth of Tests. Many aircraft affect the soil to depths of 36 inches or more; therefore, it is recommended that DCP tests be conducted to the full depth of the rod**. If a test must be discontinued short of full rod depth, a new test should be accomplished nearby.**

Table 3. Tabulated Correlation of DCP Index to CBR,
All Soil Types Other Than CH or CL

DCP Index mm/blow	in/Blow	CBR	DCP Index mm/blow	in/Blow	CBR	DCP Index mm/blow	in/Blow	CBR
<3	0.10	100	12		18	56-57	2.20	3.2
	0.11	92		0.50	17	58		3.1
	0.12	84	13		16	59-60		3.0
3		80	14	0.55	15	61-62	2.40	2.9
	0.13	76	15	0.60	14	63-64	2.50	2.8
	0.14	70	16	0.65	13	65-66	2.60	2.7
	0.15	65	17	0.70	12	67-68		2.6
	0.16	61	18-19		11	69-71	2.80	2.5
4		60	20-21	0.80	10	72-74		2.4
	0.17	57	22-23	0.90	9	75-77	3.00	2.3
	0.18	53	24-26	1.0	8	78-80		2.2
5	0.19	50	27-29		7	81-83		2.1
	0.20	47	30-34	1.20	6	84-87	3.40	2
	0.21	45	35-38	1.40	5	88-89	3.50	1.9
	0.22	43	39		4.8	92-96		1.8
	0.23	41	40		4.7	97-101	4.00	1.7
6		40	41	1.60	4.6	102-107		1.6
	0.24	39	42		4.4	108-114		1.5
	0.25	37	43		4.3	115-121		1.4
7	0.26	35	44		4.2	122-130	5.00	1.3
	0.27	34	45		4.1	131-140		1.2
	0.28	32	46	1.80	4	141-152		1.1
	0.29	31	47		3.9	153-166	6.00	1
8	0.30	30	48		3.8	166-183	7.00	0.9
9	0.35	25	49-50		3.7	184-205	8.00	0.8
	0.40	22	51	2.0	3.6	206-233	9.00	0.7
10-11		20	52		3.5	234-271	10.00	0.6
	0.45	19	53-54		3.4	272-324		0.5
			55		3.3	>324		<0.5

2.2.3.3.5. Correlation of DCP Readings to CBR.

2.2.3.3.5.1. If using manual field-plotting methods, the CBRs may be obtained from Tables 3 and 4 or Figure 14. Table 3 correlations should be used for all soil groups other than CH and CL with a CBR below 10. Table 4 correlations should be used for all CH and CL soils with a CBR less than 10. When using these tables, CBRs should be rounded to the nearest whole number. Figure 14 shows a plot of all correlations.

Table 4. Tabulated Correlation of DCP Index to CBR, CH and CL Soils

CH Soil						CL Soil					
DCP Index mm/Blow	in/Blow	CBR	DCP Index mm/Blow	in/Blow	CBR	DCP Index mm/Blow	in/Blow	CBR	DCP Index mm/Blow	in/Blow	CBR
10	0.4	35	115	4.5	3.0	19	0.7	9.6	40	1.6	2.2
15	0.6	23	120	4.7	2.9	20	0.8	8.6	41	1.6	2.1
20	0.8	17	125	4.9	2.8	21	0.8	7.8	42	1.7	2.0
25	1.0	14	130	5.1	2.7	22	0.9	7.1	43	1.7	1.9
30	1.2	12	135	5.3	2.6	23	0.9	6.5	44	1.7	1.8
35	1.4	10	140	5.5	2.5	24	0.9	6.0	45	1.8	1.7
40	1.6	8.7	145	5.7	2.4	25	1.0	5.5	46	1.8	1.6
45	1.8	7.7	150	5.9	2.3	26	1.0	5.1	47	1.9	1.6
50	2.0	7.0	155	6.1	2.3	27	1.1	4.7	48	1.9	1.5
55	2.2	5.3	160	6.3	2.2	28	1.1	4.4	49	1.9	1.4
60	2.4	5.8	165	6.5	2.1	29	1.1	4.1	50	2.0	1.4
65	2.6	5.4	170	6.7	2.0	30	1.2	3.8	51	2.0	1.3
70	2.8	5.0	>175	>6.9	<2.0	31	1.2	3.6	52	2.0	1.3
75	3.0	4.6				32	1.3	3.4	53	2.1	1.2
80	3.1	4.3				33	1.3	3.2	54	2.1	1.2
85	3.3	4.1				34	1.4	3.0	55	2.2	1.1
90	3.5	3.9				35	1.4	2.8	56	2.2	1.1
95	3.7	3.7				36	1.4	2.7	57	2.2	1.1
100	3.9	3.5				37	1.5	2.5	58	2.3	1.0
105	4.1	3.3				38	1.5	2.4	>59	>2.3	<1.0
110	4.3	3.2				39	1.5	2.3			

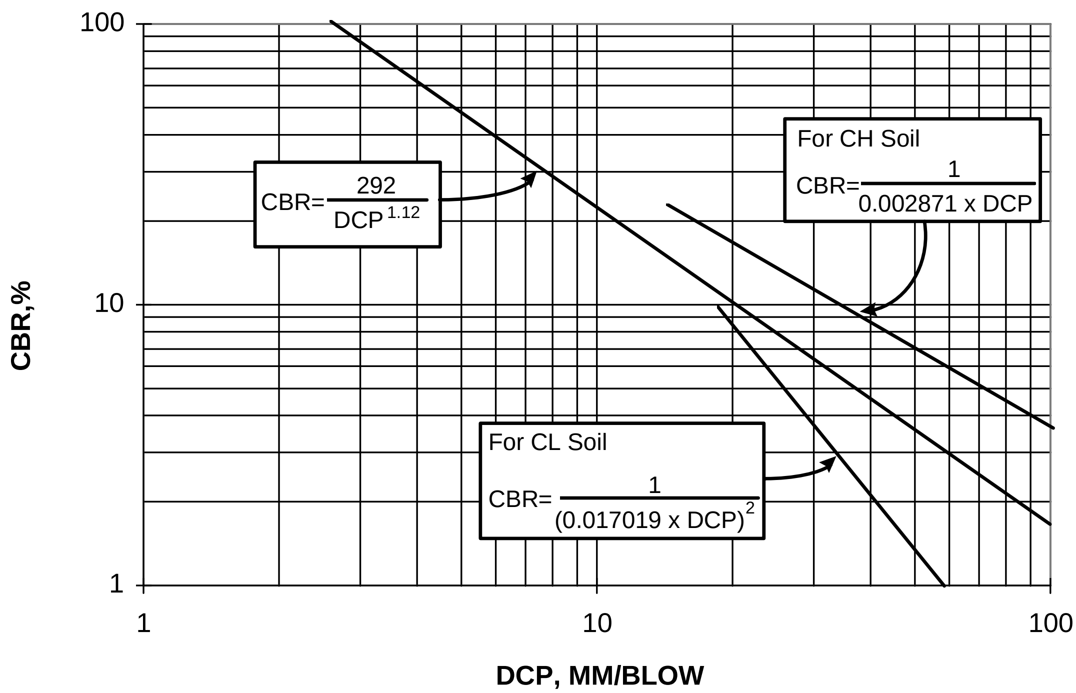


Figure 14. Plotted Correlation of DCP Index to CBR

2.2.3.3.5.2. If using the USACE Pavement-Transportation Computer Aided Structural Engineering (PCASE) DCP software program, the CBRs are computed for the user based upon the number of blows and penetration depths inputted. The DCP program will also display a graph of the CBR values in relation to the depths measured and is useful in determining layer thicknesses. The user should have extensive experience and training before readily accepting the values that the DCP program produces; if in doubt, contact HQ AFCESA.

2.2.3.3.5.3. The DCP data may also be easily plotted on graph paper and the resulting soil layer thicknesses and corresponding CBRs may be determined. Figure 15 is an example of this method.

- **Plot.** Plot the cumulative number of blows needed in a particular DCP test along one axis of the graph. Annotate the depth of penetration along the other axis. Then plot the points as recorded on the DCP data sheet.
- **Layers**. Draw straight lines tangent to or through the points that are reasonably straight. These lines indicate the soil layers with the intersecting points indicating the layer breaks. Disregard the top few measurements of the test in this process. In this example, the first layer break is located at 420 millimeters (16 inches), so the thickness of layer 1 is 16 inches. The second layer break is at 800 millimeters (31 inches), so the thickness of layer 2 is 15 inches. This is continued throughout the depth of the test.
- **DCP Index.** The layer DCP index is established by dividing the depth of penetration by the number of blows. In this example, the first straight line intersected the depth axis at 70 millimeters and the layer break point at 420 millimeters, so the depth for determination of DCP index is 350 millimeters. It took 46 blows to reach the first layer break. Dividing 350 by 46 results in a DCP index of 7.6 for this layer. DCP indexes for the remaining layers are determined the same way by using the number

of blows and depth measurements between layer breaks. The DCP index for layer 2 is 14.6 and the DCP index for layer 3 is 35.

- **CBRs.** Tables 3 and 4 are used to determine the CBRs for each layer. In this example, the soils tested were classified as SP or poorly graded sand, so Table 3 was used. The depth measurements were in millimeters, so the table was entered in the DCP index "mm/blow" columns as appropriate to find the corresponding CBRs. A CBR 32 resulted for layer 1, CBR 14 for layer 2, and CBR 5 for layer 3.

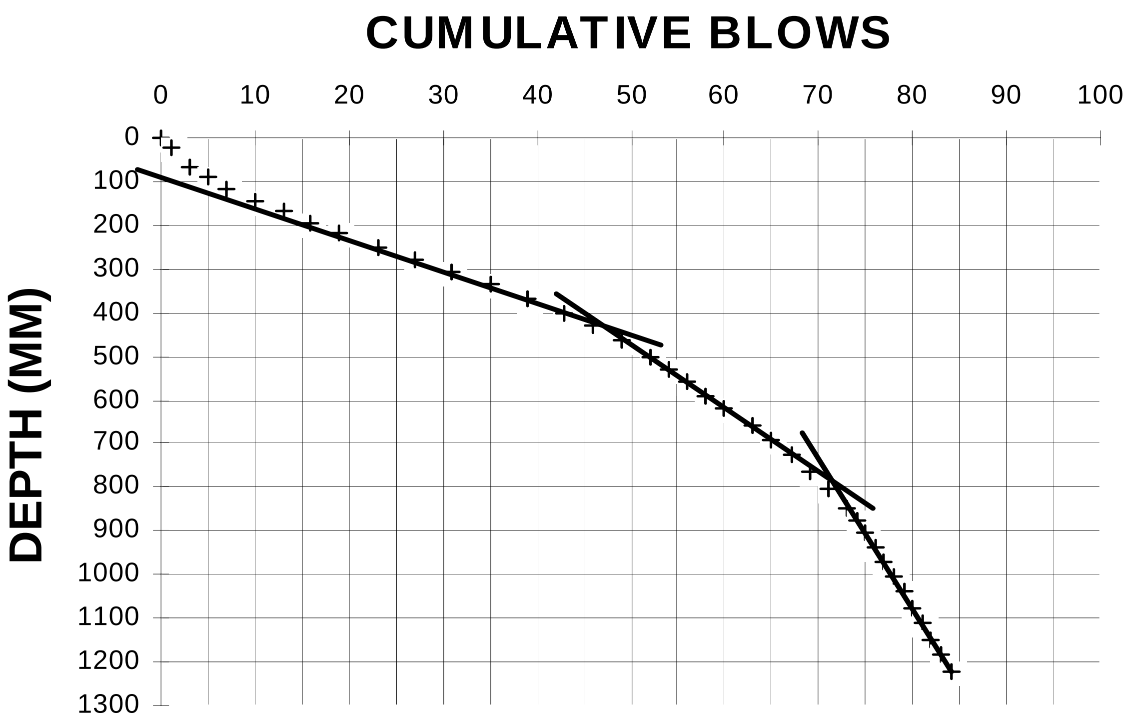


Figure 15. Manual Plot of DCP Data

2.2.3.3.6. Special Considerations.

2.2.3.3.6.1. DCP tests in highly plastic clays are generally accurate for depths to approximately 12 inches. At deeper depths, clay sticking to the lower rod may indicate higher CBR values than actually exist. Oiling the rod will help, without significantly impacting the test results. It may be wise to auger out the test hole after each 12-inch depth encountered to eliminate the clay-related friction problems and allow more accurate measurements.

2.2.3.3.6.2. Many sands occur in a loose state. Such sands when relatively dry will show low DCP index values for the top few inches and then may show increasing strength with depth. The compressing action of aircraft tires will increase the strength of sand. Aircraft operations on sands and gravels in a "quick" condition (water percolating through them) must be avoided. Evaluation of moist sands should be based upon DCP test data.

2.2.3.3.6.3. If the cone does not penetrate after 10 blows, the test should be stopped. **If the material encountered is a stabilized material or high-strength aggregate base course that does not produce accurate results when penetrated with the DCP, it should be cored or**

augured through its depth and the DCP operation resumed beneath it. An appropriate CBR should be assigned to this layer.

2.2.3.3.6.4. If large aggregate is encountered, the test should be stopped and a new test should be performed within a few feet of the first location. **The DCP is generally not suitable for soils having significant amounts of aggregate larger than 2 inches.** CBR values for impenetrable materials must be carefully selected. **If the impenetrable layer is subsurface or not identifiable, a CBR 80 should be assigned.** If the impenetrable layer is on the surface or can be identified, the following CBR values may be used:

- Graded crushed aggregate 100
- Macadam 100
- Bituminous binder 100
- Limerock 80
- Stabilized aggregate 80
- Soil cement 80
- Sand/shell or shell 80
- Sand asphalt 80

2.2.3.4. For evaluating PCC pavement structures, the soil layer CBRs must be converted to K-values (modulus of soil reaction). See Figures 16 and 17 for correlations. Table 5 gives typical K-values for different soil types and moisture contents. Figure 18 yields an effective K-value at the surface of the base course as a function of the subgrade K-value and base course thickness. CBR field data taken at different depths should be converted to K-values, and the K-values in turn plotted on Figure 18 to determine the effective K-value of each layer. **The lowest effective K-value obtained from the various layers should be used to evaluate the pavement system.**

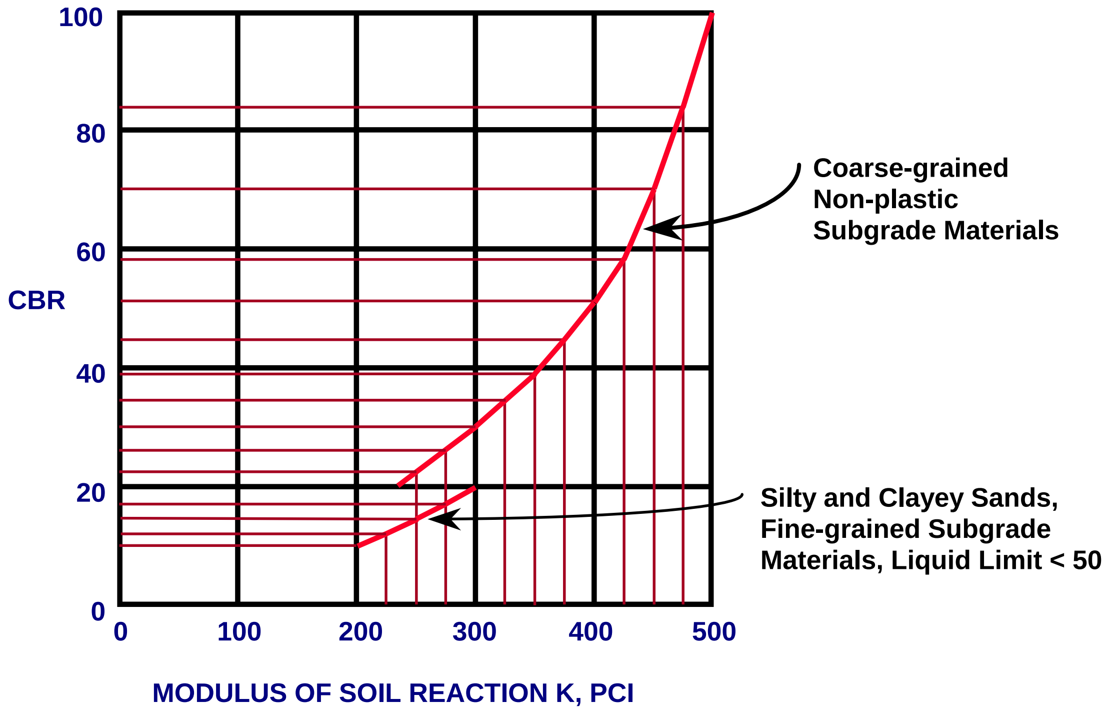


Figure 16. Correlation of CBR to Modulus of Soil Reaction K

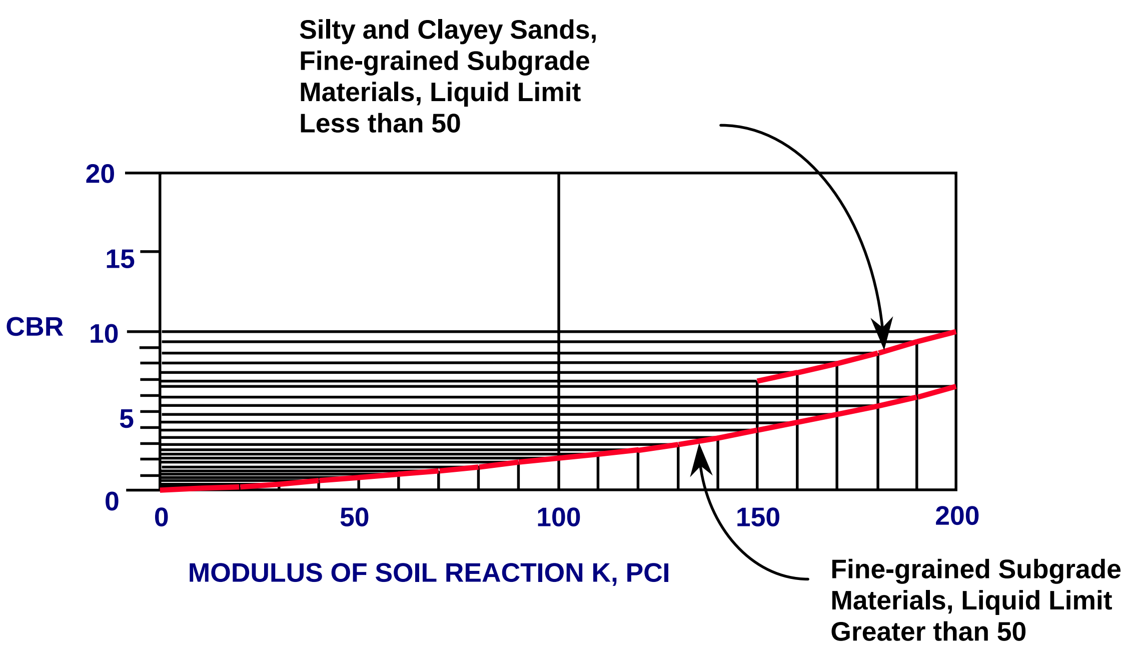


Figure 17. Correlation of CBR to Modulus of Soil Reaction K

Table 5. Typical Values – Modulus of Soil Reaction K

Type of Material	Modulus of Soil Reaction K for Moisture Content							
	1 - 4	5 - 8	9 - 12	13 - 16	17 - 20	21 - 24	25 - 28	Over 28
Silts & clays LL > 50 (OH, CH, MH)	--	175	150	125	100	75	50	25
Silts & clays LL < 50 (OL, CL, ML)	--	200	175	150	125	100	75	50
Silty & clayey sands (SM & SC)	300	250	225	200	150	--	--	--
Sand & gravelly sands (SW & SP)	350	300	250	--	--	--	--	--
Silty & clayey gravels (GM & GC)	400	350	300	250	--	--	--	

Notes: 1. Values of K shown are typical for materials having dry densities of 90 to 95% of the maximum. For materials with dry densities < 90%, reduce values by 50 PCI.

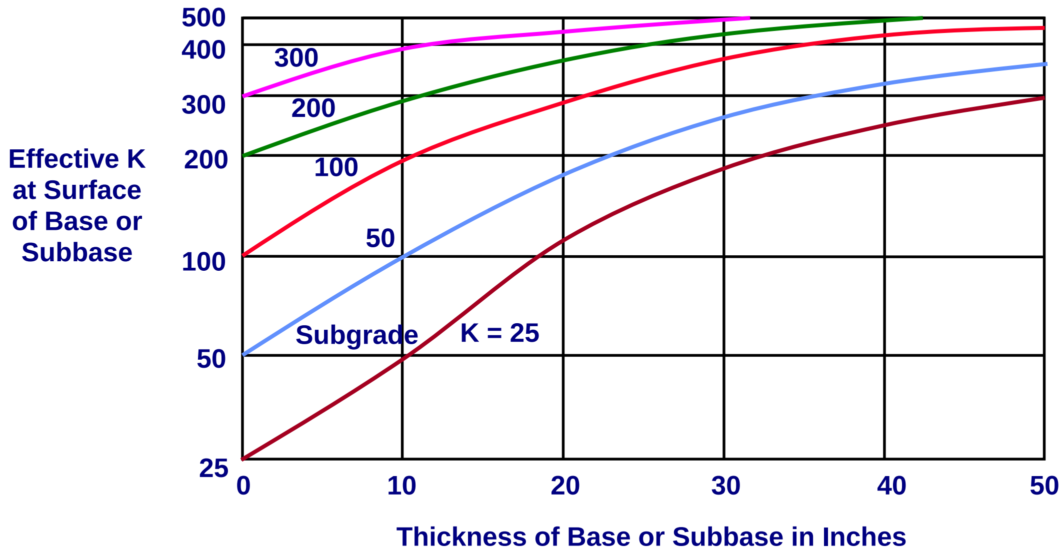


Figure 18. Effect of Base Course Thickness on Modulus of Soil Reaction

Example: Determine the correct effective K-value to be used to evaluate a rigid pavement with the following cross-section:

- 8-inch PCC
- 8-inch base course with a DCP index of 8 mm/blow
- 12-inch subbase course with a DCP index of 20 mm/blow

- Subgrade with a DCP index of 35 mm/blow

Solution:

- Step 1. Convert DCP index of each soil layer to CBR (see Table 3)
  DCP Index of 8 mm/blow = CBR 30
  DCP Index of 20 mm/blow = CBR 10
  DCP Index of 35 mm/blow = CBR 5
- Step 2. Convert CBR of each soil layer to K-value (see Figures 16 and 17)
  CBR 30 = 300 K
  CBR 10 = 200 K
  CBR 5 = 170 K
- Step 3. Convert K-value of each layer to effective K-value (see Figure 18)
  300 K directly beneath PCC yields an effective K of 300
  200 K 8 inches below the PCC yields an effective K of 275
  170 K 20 inches below the PCC yields an effective K of 325
- In this example, the subbase yields the lowest effective K-value. A K-value of 275 should be used to evaluate this rigid pavement structure.

2.2.3.5. Other Strength Factors.

2.2.3.5.1. Surface and Subsurface Drainage.

- Locate depth of water table
- Look at contours in area, signs of surface drainage problems, and wet or swampy areas
- Coarse-grained soils have better internal drainage
- Moisture content plays a significant role in bearing capacity
- Note the size and depth of any storm drain culverts under the pavement

2.2.3.5.2. Cut/Fill Areas. Cut/fill areas indicate possible feature changes based on changing subsurface layers.

2.2.3.5.3. Frost Areas. The impact of frost need not be considered in an expedient evaluation. When performing a sustainment evaluation and the operational period will extend into the thaw-weakened season or performing a permanent evaluation, frost must be considered.

2.2.3.5.3.1. Subgrade strengths are reduced significantly during thaw periods if the potential exists for structural weakening due to frost. **Detrimental frost action will occur only if the subgrade contains frost-susceptible materials, frost penetrates the susceptible materials, and an ample supply of ground water is available. If all three conditions exist, look for signs of frost action. If none exist, do not consider frost in the evaluation.**

2.2.3.5.3.2. Frost Area Soil Support Indexes (FASSI) are used in lieu of CBRs for evaluation of flexible pavements.

- F1 and S1 Soils = 9.0 FASSI
- F2 and S2 Soils = 6.5 FASSI
- F3 and F4 Soils = 3.5 FASSI

2.2.3.5.3.3. When evaluating rigid pavements in frost conditions, Frost Area Index of Reaction (FAIR) values are used in lieu of K-values (see Figure 19).

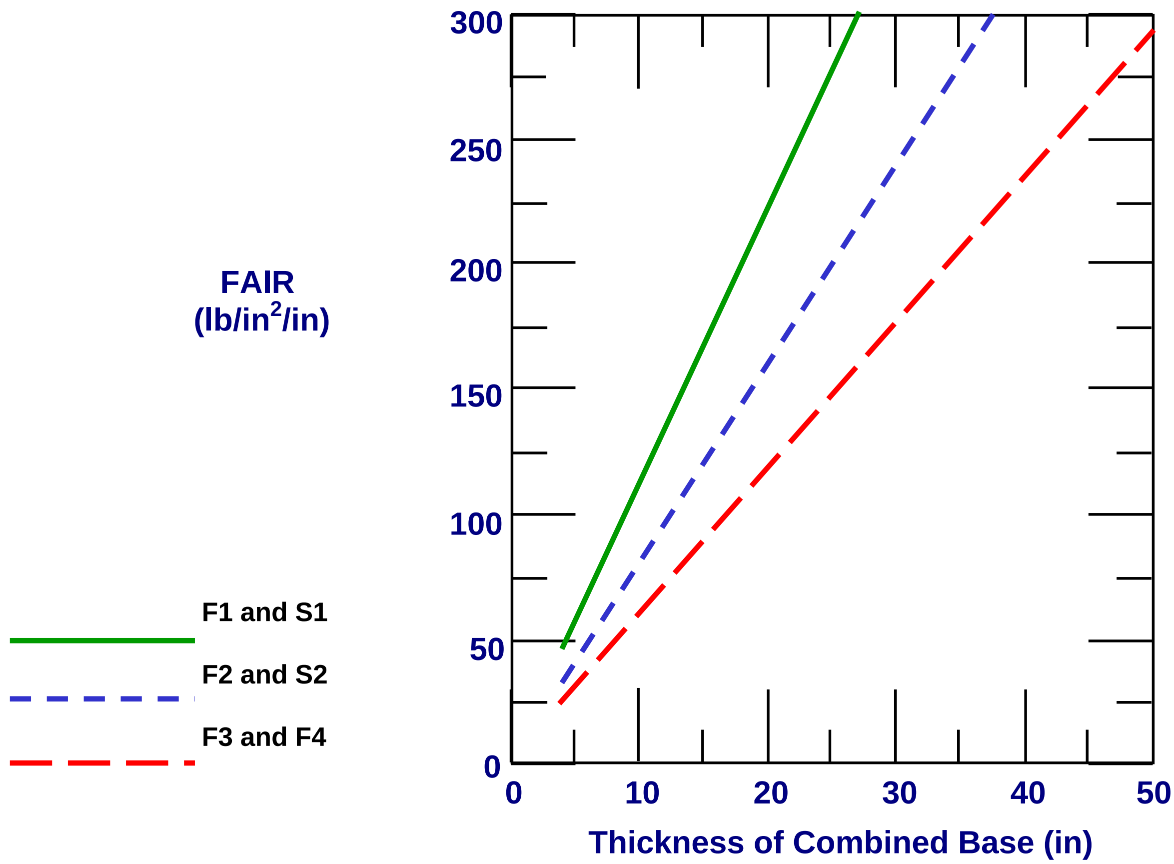


Figure 19. FAIR Values

2.2.3.5.3.4. Clays, silts, and some gravelly and sandy soils with high percentages of fines are susceptible to frost (see Table 6).

Table 6. Frost Design Soil Classifications

Frost Group	Kind of Soil	Percentage Finer than 0.02 mm by Weight	Percentage Finer than #200 Sieve by Weight*	Typical Soil Types under USCS
NFS†	(a) Gravels Crushed stone Crushed rock	0 - 1.5	0 - 3	GW, GP
	(b) Sands	0 - 3	0 - 7	SW, SP
PFS‡	(a) Gravels Crushed stone Crushed rock	1.5 - 3	3 - 7	GW, GP
	(b) Sands	3 - 10		SW, SP
S 1	Gravelly soils	3 - 6	7 - 15	GW, GP, GW-GM, GP-GM, GW-GC, GP-GC
S 2	Sandy soils	3 - 6	7 - 15	SW, SP, SW-SM, SP-SM, SW-SC, SP-SC
F 1	Gravelly soils	6 - 10		GM, GC, GM-GC, GW-GM, GP-GM, GW-GC, GP-GC
F 2	(a) Gravelly soils	10 - 20		GM, GC, GM-GC, GW-GM, GP-GM, GW-GC, GP-GC
	(b) Sands	6 - 15		SM, SW-SM, SP-SM, SC, SW-SC, SP-SC, SM-SC
F 3	(a) Gravelly soils	Over 20		GM, GC, GM-GC
	(b) Sands, except very fine silty sands	Over 15		SM, SC, SM-SC
	(c) Clays, PI>12	--		CL, CH
F 4	(a) Silts	--		ML, MH, ML-CL
	(b) Very fine silty sands	Over 15		SM, SC, SM-SC
	(c) Clays, PI<12	--		CL, ML-CL
	(d) Varved clays or other fine-grained banded sediments	--		CL or CH layered with ML, MH, ML-CL, SM, SC, or SM-SC

* These are rough estimates. If there are surface indications of frost action, then frost susceptibility tests should be conducted. Use only if percent finer than 0.02 mm is not available.

† Nonfrost-susceptible

‡ Possibly frost-susceptible, requires lab test for void ratio to determine frost design soil classification.
Gravel with void ratio > 0.25 would be NFS
Gravel with void ratio < 0.25 would be S 1
Sands with void ratio > 0.30 would be NFS
Sands with void ratio < 0.30 would be S 2 or F 2

2.2.3.5.3.5. Areas of frost heave, when no longer frozen, may have large subsurface voids and will not support projected loads.

2.2.3.5.4. Wet Climate.

2.2.3.5.4.1. Soil layer strengths in areas subject to heavy seasonal rains or flooding may react similarly to those in frost-susceptible areas. This is particularly true in the case of fine-grained materials containing clays and/or silts where there is no adequate surface seal.

2.2.3.5.4.2. Moisture conditions at the time of testing should be documented (dry, damp, or wet) and anticipated conditions for the projected use period must be considered in determining the validity of test data for intended aircraft operations.

3. Aircraft Operational Requirements. Obtain aircraft operational requirements from the site operations officer, local command section, or the tasking office of primary responsibility (OPR).

3.1. Data Required.

3.1.1. Aircraft Types. Data essential for evaluation can be extracted from various sources. Gear configuration, for example, establishes the traffic paths in relation to pavement centerlines and determines test locations. Testing should usually be done in the main gear wheel paths. Aircraft weights are shown in Table 7. Several sources in DOD provide data on aircraft characteristics:

- HQ AFCESA, *Aircraft Characteristics for Airfield Pavement Design and Evaluation* (1990), Tyndall AFB, Florida
- U.S. Army Corps of Engineers (USACE), Engineer Technical Letter (ETL) 1110-3-394, *Aircraft Characteristics for Airfield-Heliport Design and Evaluation* (1991)
- U.S. Navy Aircraft Characteristics Web site, http://www.efdlant.navfac.navy.mil/criteria/

Table 7. Aircraft Characteristics

Aircraft	Minimum Weight (pounds)	Maximum Weight (pounds)	Length (feet)	Wingspan (feet)	Runway Length (feet)	Runway Width (feet)	Taxiway Width (feet)
C-130 Hercules	69,000	175,000	*99.5	132.6	3,500	60	30
C-141 Starlifter	144,000	345,000	168.3	160.0	6,000	98	50
C-5 Galaxy	375,000	837,000	247.8	222.7	6,000	148	75
C-17 Globemaster III	279,000	585,000	174.0	169.8	3,500	90	60
KC-10 Extender	270,000	590,000	181.6	165.3	7,000	148	75
KC-135 Stratotanker	135,000	302,000	136.2	*130.8	7,000	148	75
A-10 Thunderbolt	28,000	51,000	53.3	57.5	10,000	150	75
F-15 Eagle	31,700	81,000	63.8	42.8	10,000	150	75
F-16 Fighting Falcon	17,400	37,500	49.5	32.8	10,000	150	75

Notes: * Length or width varies per aircraft model number.
Maximum weight for semi-prepared surface is 447,000 pounds.
Runway lengths are given for planning purposes only—actual requirements should be obtained from operations personnel.

Aircraft	Flexible Pavement ACNs				Rigid Pavement ACNs				LCN
	A	B	C	D	A	B	C	D	
C-130 Hercules	27	32	35	41	31	34	37	40	45
C-141 Starlifter	47	54	66	81	46	55	64	71	75
C-5 Galaxy	36	40	49	67	29	35	45	56	37
C-17 Globemaster III	50	57	68	90	52	50	54	66	62
KC-10 Extender	56	61	74	101	45	55	67	77	82
KC-135 Stratotanker	36	40	49	63	31	38	46	52	67
A-10 Thunderbolt	20	20	20	20	20	20	20	20	27
F-15 Eagle	33	33	33	33	37	37	37	37	57
F-16 Fighting Falcon	16	16	16	16	18	18	18	18	26

3.1.2. Loads. Loads are the gross weights of anticipated mission aircraft, including cargo and fuel.

3.1.3. Traffic Volume. Traffic volume is the expected number of passes anticipated for each aircraft type. For a runway, passes are determined by the number of aircraft movements across an imaginary transverse line placed within 500 feet of the end of the runway. Simply stated, it is one aircraft movement over a given area. For taxiways and aprons, passes are determined by the number of aircraft cycles across a line on the primary taxiway that connects the runway and parking areas. The configuration of the airfield influences the number of passes per mission. In a case where a parallel taxiway is available and the aircraft lands and takes off in the same direction, one landing and one takeoff would equal one pass on the runway.

3.1.4. Turnarounds/Taxi Routes. Aircraft ground operations such as turnarounds and taxi routes determine the designation of feature types and resulting gross loads. For example, if back-taxiing were required on the runway after each landing and before takeoff, the number of passes per mission would increase.

4. Conduct Cursory Surface Condition Assessment.

4.1. Pavement Condition Index (PCI) for Rigid or Flexible Pavement Surfaces.

4.1.1. The purpose of a PCI survey in contingency operations is three-fold: first, a visual survey of the pavement surface can provide information on apparent structural integrity, operational condition, and projected performance to help identify potential pavement problems which would preclude aircraft operations; second, these ratings will impact the allowable gross load (AGL) or pass level computations—**specifically, if the feature is rated poor or below, the AGLs will be reduced by 25 percent**; third, the PCI ratings, with supporting photographs, if accomplished prior to contingency operations, will serve as a baseline to assess any pavement damage caused by aircraft ground operations. This is important in the determination of costs or liabilities associated with aircraft deployments.

4.1.2. A cursory inspection of the pavement features should be performed and the distress types, quantities, and severity levels should be identified as described in American Society for Testing and Materials (ASTM) D5340-98, *Standard Test Method for Airport Pavement Condition Index Surveys*. The features should then be assigned overall condition ratings. Emphasis should be placed on structural- or foreign-object-damage- (FOD) related distresses. UFC 3-270-05, *Paver, Concrete Surfaced Airfields Pavement Condition Index (PCI)*, and UFC 3-270-06, *Paver, Asphalt Surfaced Airfields Pavement Condition Index (PCI)*, should be used as guides for this inspection.

4.1.3. A cursory visual survey is not as detailed as outlined in ASTM D5340-98; however, the pavements are categorized in general terms based on this guidance. Pavement condition ratings range from EXCELLENT (like new) to FAILED (unsafe for aircraft operations). **These ratings are a qualitative assessment of the pavement surface condition and should not be confused with the structural capacity of a pavement.** For example, a pavement surface may rate EXCELLENT but have underlying pavement or soil conditions that could result in pavement failure under the applied load of a given aircraft. On the other hand, a pavement may be structurally sound but the surface condition may be hazardous for aircraft traffic (e.g., FOD). The pavement condition rating scale used in this type of analysis is shown in Figure 20 and is described in more detail in Table 8.

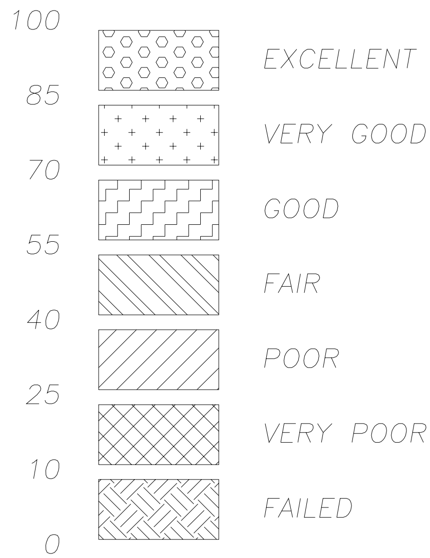


Figure 20. PCI Rating Scale

Table 8. PCI Rating Descriptions

Condition	Rating	Definition
Excellent	86 - 100	Pavement has minor or no distresses and will require only routine maintenance.
Very Good	71 - 85	Pavement has scattered low-severity distresses that should need only routine maintenance.
Good	56 - 70	Pavement has a combination of generally low- and medium-severity distresses. Maintenance and repair needs should be routine to major in the near term.
Fair	41 - 55	Pavement has low-, medium-, and high-severity distresses that probably cause some operational problems. Maintenance and repair needs should range from routine to reconstruction in the near term.
Poor	26 - 40	Pavement has predominantly medium- and high-severity distresses causing considerable maintenance and operational problems. Near-term maintenance and repair needs will be intensive.
Very Poor	11 - 25	Pavement has mainly high-severity distresses that cause operational restrictions. Repair needs are immediate.
Failed	0 - 10	Pavement deterioration has progressed to the point that safe aircraft operations are no longer possible. Complete reconstruction is required.

4.1.4. When performing a PCI in a contingency situation, emphasis should be placed on structural- or FOD-related distresses.

4.1.4.1. Flexible Pavement Structural Distresses:

- Alligator or fatigue cracking occurs primarily in areas where aircraft traffic is overloading the pavement and is considered a major structural distress.
- Corrugation caused by traffic action combined with an unstable pavement surface or base.
- Depression caused by settlement of supporting soil layers due to overloading or poor initial construction.
- Rutting caused by consolidation or lateral movement of the pavement, base, and/or subgrade due to traffic loads that can lead to major structural failure.
- Slippage cracking produced in areas of braking and turning when there is an unstable surface mix or poor bond between the surface and underlying pavement layer.

4.1.4.2. Rigid Pavement Structural Distresses:

- Blow-up occurs at joints or at junctures with PCC and AC pavements and has severe damage potential to aircraft.
- Corner break can be caused by load repetitions and/or loss of subgrade support.
- Longitudinal, transverse, and diagonal cracks can be caused by load repetitions and are considered major structural distresses of medium or high severity.
- Pumping indicates poor joint sealer and loss of support, which will lead to cracking under repeated loads.
- Settlement or faulting caused by upheaval or consolidation.
- Shattered slab/intersecting cracks due to overloading or inadequate support.

4.2. Semi-Prepared Airfield Condition Index (SPACI) for Unsurfaced or Aggregate Surfaces.

4.2.1. Procedure. Evaluation team personnel must have the ability to quickly and accurately assess the surface condition of a semi-prepared airfield and determine its suitability for aircraft operations. ETL 97-9, *Criteria and Guidance for C-17 Contingency and Training Operations on Semi-prepared Airfields*, provides detailed guidance on the rating system for these airfields. The rating system, which prescribes the procedures necessary to determine the SPACI, is useful for engineering units tasked to maintain the airfield, but for contingency operations a more simplified method is used to determine the impact of surface distresses.

4.2.1.1. The first step is to divide the airfield into sections (see Figure 21). The sections can coincide with the marker panels used to delineate the runway edges.

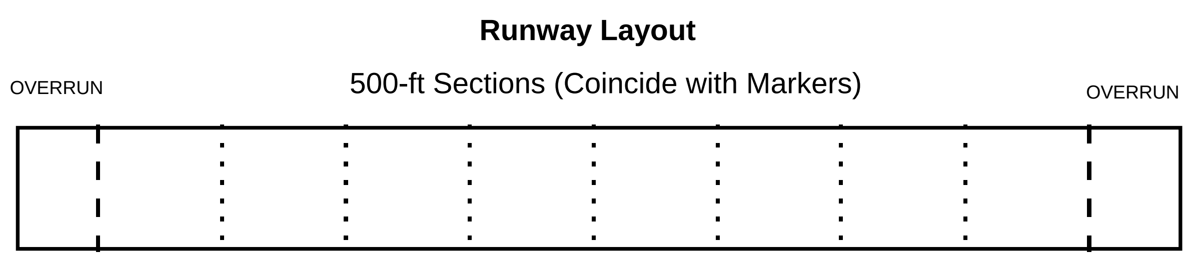


Figure 21. Semi-prepared Airfield Layout

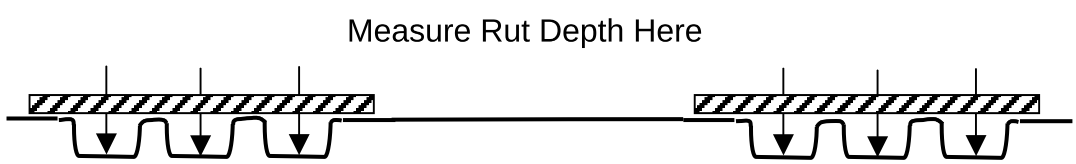
4.2.1.2. The second step is to locate the various surface distresses, plot them on the runway layout, and record their severity levels. Continue to track the development and degradation of the distresses through subsequent aircraft operations and determine airfield suitability.

4.2.4. Distress Types. There are seven distress types for semi-prepared airfields:

4.2.4.1. Potholes. Potholes are bowl-shaped depressions in the airfield surface. Once potholes have begun to form, they will continue to disintegrate because of loosening surface material or weak spots in the underlying soil. The number and location of potholes can be critical to aircraft operations. To determine the severity, measure the depths and diameters of the largest potholes. Severity levels are shown in Table 9. If the potholes have hard, abrupt, vertical sides, refer to stabilized layer failure criteria as described in paragraph 4.2.4.7.

4.2.4.2. Loose Aggregate. Loose aggregate is small stones 0.25 inch or larger that have separated from the soil binder. In large enough quantities and sizes, it can create problems. Rocks over 4 inches in diameter must be removed from the operational surface. If material crushes underfoot it is not considered loose aggregate. To determine the severity, estimate coverage on the airfield. Severity levels are shown in Table 9.

4.2.4.3. Ruts. Ruts are surface depressions in the wheel paths that generally run parallel with the centerline or direction of traffic. To measure, lay a straightedge across the ruts with both ends resting on the solid runway surface with the loose rolling resistant material (RRM) removed. Measure the depth of the three deepest ruts on each side, from the bottom of the straight edge to the solid ground in the bottom of the rut (see Figure 22). Use the maximum depth of the six measurements for that location. Rut width does not affect severity. Generally check rut depths in the touchdown area, in the primary braking area, at the point of rotation, and in the last 500 feet of the runway or in other areas where the ruts are more severe. For a typical 4,000-foot runway, take one set of measurements at approximately 4+00, 10+00, 20+00, and 35+00. The maximum rut depth measured determines the severity. Severity levels are shown in Table 9.



Location 1 Measurements	Location 2 Measurements	Location 3 Measurements	Location 4 Measurements
1. ____ 4. ____	1. ____ 4. ____	1. ____ 4. ____	1. ____ 4. ____
2. ____ 5. ____	2. ____ 5. ____	2. ____ 5. ____	2. ____ 5. ____
3. ____ 6. ____	3. ____ 6. ____	3. ____ 6. ____	3. ____ 6. ____
Loc 1 Max= ____	Loc 2 Max= ____	Loc 3 Max= ____	Loc 4 Max= ____

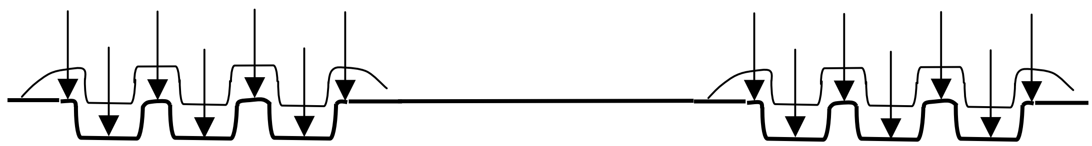
Runway Maximum Rut Depth = ______

Figure 22. Rut Depth Measurements

4.2.4.4. Rolling Resistant Material (RRM). RRM is any type of loose or unbound material that separates from the solid base and lies on top of the surface and in ruts. In sufficient quantities it increases the rolling resistance, thereby increasing the amount of runway required for takeoffs.

It is more prevalent in dry soils and is a byproduct of severe rutting. To measure, stick a ruler into the RRM until you hit solid ground and read the number on the ruler at the top of the RRM to the nearest 0.25 inch. Take seven measurements in each main gear path and average those measurements (see Figure 23). Determine the average RRM depth by averaging the measurements in the touchdown area, in the primary braking area, at the point of rotation, and in the last 500 feet of the runway. For a typical 4,000-foot runway, take one set of measurements at approximately 4+00, 10+00, 20+00, and 35+00 and average those four sets of measurements. Severity levels are shown in Table 9.

Measure Thickness of RRM Here



Location 1 Measurements		Location 2 Measurements		Location 3 Measurements		Location 4 Measurements	
1. ____	8. ____	1. ____	8. ____	1. ____	8. ____	1. ____	8. ____
2. ____	9. ____	2. ____	9. ____	2. ____	9. ____	2. ____	9. ____
3. ____	10. ____	3. ____	10. ____	3. ____	10. ____	3. ____	10. ____
4. ____	11. ____	4. ____	11. ____	4. ____	11. ____	4. ____	11. ____
5. ____	12. ____	5. ____	12. ____	5. ____	12. ____	5. ____	12. ____
6. ____	13. ____	6. ____	13. ____	6. ____	13. ____	6. ____	13. ____
7. ____	14. ____	7. ____	14. ____	7. ____	14. ____	7. ____	14. ____
Loc 1 Avg= ____		Loc 2 Avg= ____		Loc 3 Avg= ____		Loc 4 Avg= ____	

Runway RRM Average Depth = ______

Figure 23. RRM Depth Measurements

4.2.4.5. Dust. Dust is fine material that becomes airborne when disturbed. These fines separate from the surface and become a significant problem for personnel, trailing aircraft, and the environment. To determine the severity, drive a ground vehicle quickly down the runway and note the visibility through the trailing dust cloud. Dust is difficult to control, so one must be aware of the problem to adequately phase aircraft operations. Severity levels are shown in Table 9.

4.2.4.6. Jet Blast Erosion. Jet blast erosion occurs when the top layer of soil is blown or stripped away in areas scoured by engine blast. Jet blast erosion outside of trafficked areas can be ignored. Jet blast erosion is characterized by no evidence of loose aggregate or by a serrated or dimpled surface. To determine the severity, measure the depth of the erosion. Severity levels are shown in Table 9.

4.2.4.7. Stabilized Layer Failure. Stabilized layer failure occurs in areas of a stabilized surface layer that begin to crack and delaminate; it is a progressive failure. It first appears as cracks that become more prevalent and begin to interconnect and resemble alligator cracking. These pieces then separate from the surface. This creates a dangerous FOD problem as well as leaving abrupt vertical edges in the surface that may cause gear damage. To determine the severity, measure the depth of the failure. Severity levels are shown in Table 9.

4.2.5. Distress Severities. Distress severities are coded as green, amber, or red.

- Green indicates a low risk to aircraft operations.
- Amber indicates a medium risk and identifies the need for repairs.
- Red indicates high-risk operations and identifies areas that should be repaired before subsequent aircraft operations.

Table 9 contains the criteria used to determine the impact of surface distresses on C-17 operations. A similar chart for C-130 operations will be added to this manual at a later date.

Table 9. Distress Severity Levels for C-17 Operations

Distress Types	Green	Amber	Red
Potholes	< 4 inches deep and/or < 15 inches in diameter	4 to 9 inches deep and > 15 inches in diameter	> 9 inches deep and > 15 inches in diameter
Loose aggregate	Covers < 1/10 of section	Covers between 1/10 and 1/2 of section	Covers > 1/2 of section
Ruts	Exist but < 4 inches deep	4 to 9 inches deep	> 9 inches deep
RRM	Exist but < 3.5 inches deep	3.5 to 7.75 inches deep	> 7.75 inches deep
Dust	Does not obstruct visibility	Partially obstructs visibility	Thick; obstructs visibility
Jet blast erosion	Exist but < 1 inch deep	1 to 3 inches deep	> 3 inches deep
Stabilized layer failure	Exist but < 1 inch deep	1 to 2 inches deep	> 2 inches deep

Notes: 1. These limits are based upon tests of soils in arid environments and may be too high for soils in more humid environments.
2. Potholes, ruts, and RRM are considered major distresses. Depending upon actual distress location, any distress types categorized as Red may cause the overall condition of the airfield to be Red.

5. Refine Airfield Layout/Compile Summary of Physical Property Data (PPD).

5.1. Update the airfield layout based upon aircraft operational requirements, pavement condition assessment, and results of field test data.

5.1.1. For expedient evaluations, because of the limited number of tests, each DCP test location should be entered on the PPD. The weakest test location on the runway is the controlling test for the runway and will be used to determine the runway load-bearing capability. This is true in any case where multiple tests are performed on a given area (taxiway or apron).

5.1.2. For sustainment or permanent evaluations, each feature should now be distinguishable by the characteristics of pavement type, thickness, and condition; subsurface layer types, thicknesses, and strengths; construction history; pavement use; and traffic type (see Figure 2).

One method to consolidate the cross-section or pavement system profile data obtained from field tests and construction history into specific features is to:

5.1.2.1. Arrange pavement and soil profile data in relation to the actual test locations on the airfield. This will show the range of values and relationship of any given test location data to that at adjacent test locations.

5.1.2.2. Group those containing common characteristics into features.

5.1.2.3. Establish the representative profile for each feature. In most cases, the CBR values selected for a feature should be a low average (85% of average, but never lower than the lowest measured CBRs) of those collected from all the test locations within the feature, but this is not always true. Conditions are seldom uniform and sound engineering judgment should be used.

5.2. Compile the characteristics for test location (expedient evaluation) or feature (sustainment or permanent evaluation) into the Summary of PPD. This information will be used to determine the AGLs and/or allowable passes for the airfield (see Figure 24). The PPD should be filled out as follows:

5.2.1. Facility, Feature: For expedient evaluations, enter the test location number. For sustainment or permanent evaluations, enter the feature designation.

5.2.2. Facility, Ident: Area designation, e.g., Runway 09/27, Taxiway C, Transient Apron.

5.2.3. Facility, Length: For expedient evaluations, enter the length of the area designation. For sustainment or permanent evaluations, enter the feature length.

5.2.4. Facility, Width: For expedient evaluations, enter the width of the area designation. For sustainment or permanent evaluations, enter the feature width.

5.2.5. Facility, Cond: Enter the surface PCI condition rating.

5.2.6. Pavement, Thick: Enter the thickness in inches of each layer of pavement.

5.2.7. Pavement, Descrip: Enter the pavement type (see paragraph 1.2.1) of each layer of pavement. If evaluating a semi-prepared or unsurfaced airfield, do not enter anything in the pavement fields. Enter the surface layer as the base course.

5.2.8. Pavement, Flex: If evaluating as a rigid pavement, enter the flexural strength. If evaluating as a flexible pavement, no entry is required.

5.2.9. Base Course, Thick: Enter the thickness in inches of each soil layer measured, beginning with the soil layer immediately under the pavement layer and progressing downward to the subgrade.

5.2.10. Base Course, Descrip: Enter the USCS soil type (see Appendix A), if known, for each soil layer, beginning with the soil layer immediately under the pavement layer and progressing downward to the subgrade. If uncertain of the USCS soil types, do not use USCS symbols, but describe the soils.

5.2.11. Base Course, K or CBR: Enter the measured strength of each soil layer. **If a feature or test location is evaluated as a flexible (asphalt) or semi-prepared pavement, CBR values are recorded in this column. If the feature or test location is evaluated as a rigid (concrete) pavement, K-values are recorded in this column.**

5.2.12. Subgrade, Descrip: Enter the USCS soil type (see Appendix A), if known, for the subgrade soil. If uncertain of USCS soil type, do not use a USCS symbol, but describe the soil.

5.2.13. Subgrade, K or CBR: Enter the measured subgrade strength**. If a feature or test location is evaluated as a flexible (asphalt) or semi-prepared pavement, CBR values are recorded in this column. If the feature or test location is evaluated as a rigid (concrete) pavement, K-values are recorded in this column.**

SUMMARY of PHYSICAL PROPERTY DATA												
FACILTY					PAVEMENT			BASE COURSE			SUBGRADE	
Feature	Ident	Length (ft)	Width (ft)	Cond	Thick (in)	Descrip	Flex (psi)	Thick (in)	Descrip	K or CBR	Descrip	K or CBR

Figure 24. Summary of PPD Sheet

Note: Only one K-value is entered on the PPD for a given feature. Once the K-values and, in turn, effective K-values for each layer are computed, the initially computed K-value for the controlling layer or layer that produces the lowest effective K-value is entered on the PPD for that layer.

6. Determine AGLs/Allowable Passes.

6.1. Semi-prepared (Unsurfaced, Expedient-Surfaced, or Aggregate-Surfaced) Airfields. Two steps are required to manually evaluate semi-prepared airfields: first, evaluate for the strength of the surface layer; second, evaluate for the thickness of the surface layer and the strengths and thicknesses of underlying layers.

6.1.1. Evaluate Surface Layer Strength.

- Select the soil surface strength requirements chart for the desired aircraft from Appendix B.

- Enter the left of the chart at the measured CBR of the surface layer and project a line horizontally to intersect with the appropriate aircraft weight.
- At that point, project a line down vertically to determine the number of passes the surface layer will support.

6.1.2. Evaluate Surface Layer Thickness.

- Select the chart from Appendix B for the desired aircraft.
- Using the layer data from the PPD, enter the top of the chart with the thickness of the surface layer. Draw a vertical line (Line 1) downward through the aircraft pass levels. Also enter the bottom of the chart at the desired gross weight; draw a line vertically to the curve depicting the CBR of the layer immediately beneath the surface layer, then horizontally to intersect Line 1. This point of intersection defines the allowable number of passes. If this number is equal to or exceeds the number of passes computed during the evaluation of the surface layer strength, then the thickness of the surface layer is adequate. If not, then the lower number of passes is used.

Note: This step evaluates the layer immediately beneath the surface layer as well as the thickness of the surface layer.

6.1.3. Evaluate Remaining Subsurface Layers. Repeat this procedure for each soil layer. Enter the top of the chart with the thickness above the layer being evaluated and use the CBR of the layer being evaluated. **The layer that produces the lowest allowable number of passes is the controlling layer for the evaluation.**

Example: Determine the allowable number of passes for a 400,000-pound C-17 aircraft on the following soil cross-section:

- 8-inch aggregate surface course, CBR 20
- 8-inch subbase course, CBR 15
- Subgrade, CBR 5

Solution:

- Step 1. Evaluate surface course strength (see Figure 25):
    - Select the soil surface strength requirements chart for the C-17 (Figure B-5).
    - Enter the chart at 20 CBR and project a line until it intersects with 400 passes.
    - At this point, project a vertical line downward to read approximately 6,800 passes.

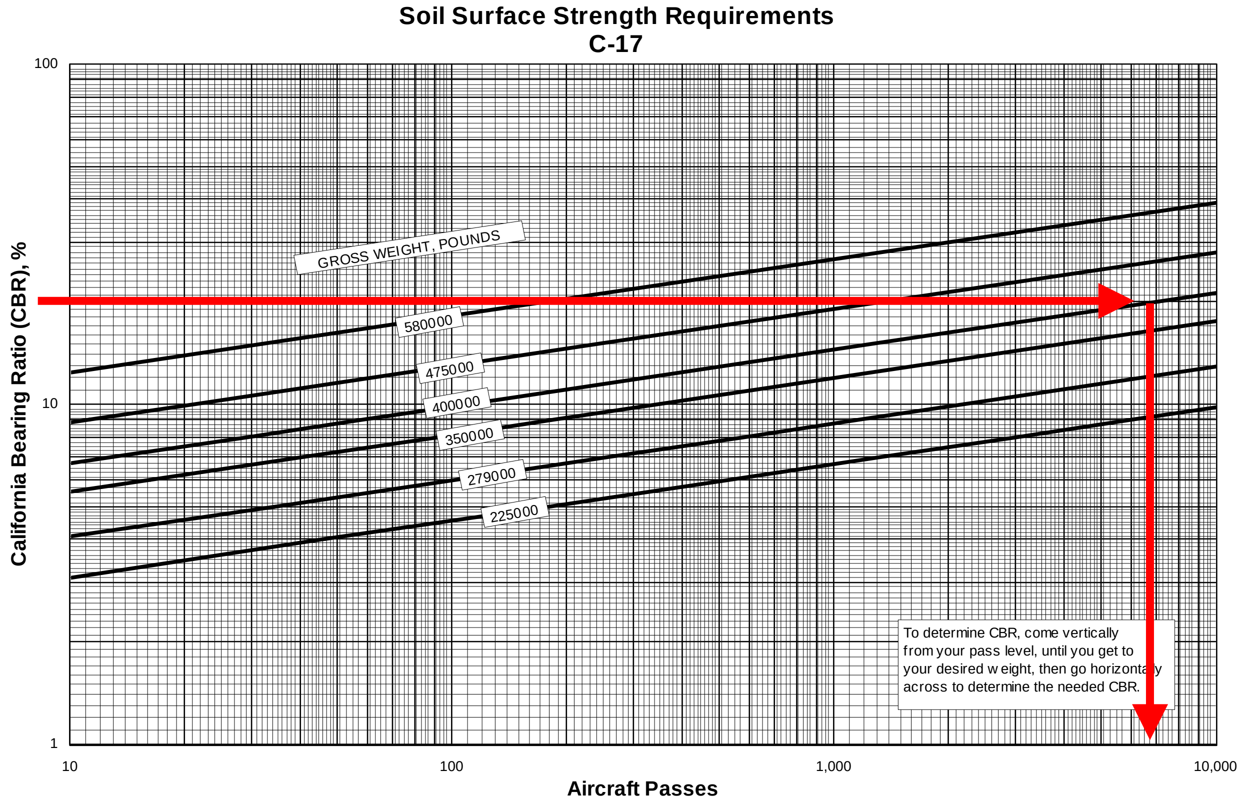


Figure 25. Example Evaluation of Surface Strength on Semi-prepared Airfield for C-17 Operations

- Step 2. Evaluate surface layer thickness (see Figure 26):
    - Select the aggregate surfaced evaluation chart for the C-17 (Figure B-6).
    - Enter the top of the chart at 8 inches drawing a vertical line (Line 1) downward through the aircraft pass curves.
    - Enter the bottom of the chart at 400,000 pounds and draw a vertical line up to the 15 CBR curve, then horizontally to intersect with Line 1.
    - The point of intersection indicates an allowable pass number of approximately 1,500.

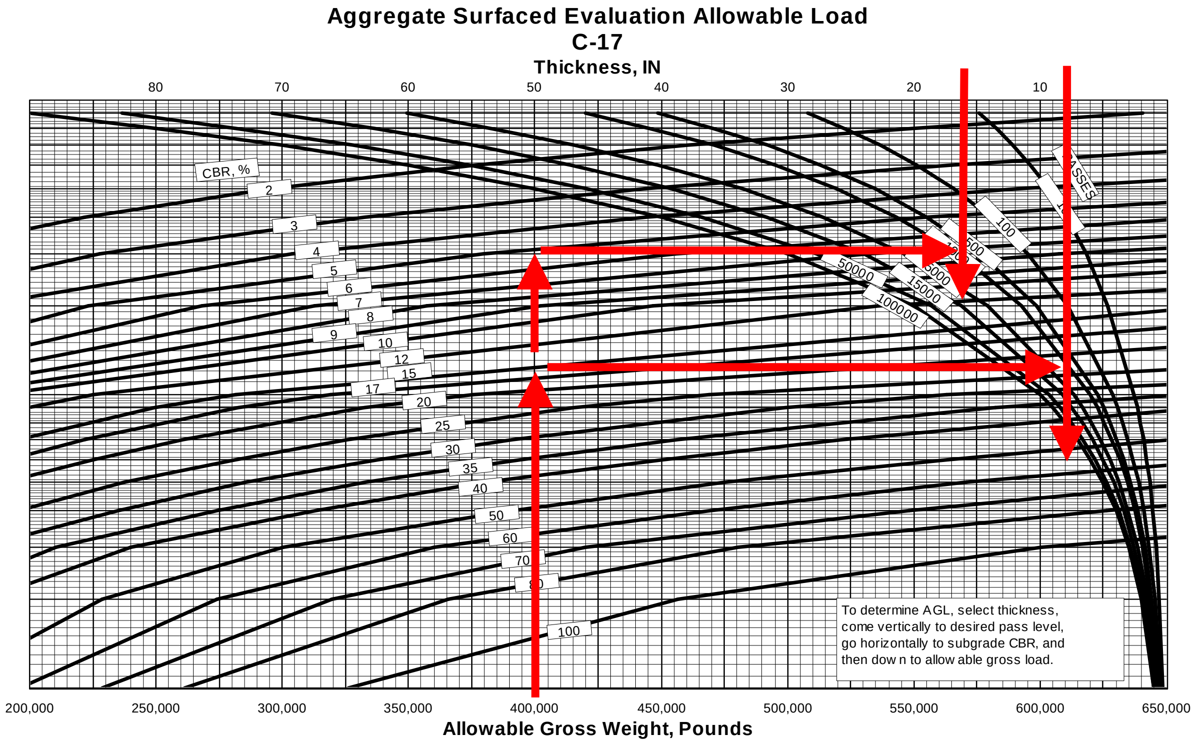


Figure 26. Example Evaluation of Subsurface Layers on Semi-prepared Airfield for C-17 Operations

- Step 3. Evaluate the subgrade:
  - Enter the top of the chart at 16 inches drawing a vertical line (Line 1) downward through the aircraft passes.
  - Enter the bottom of the chart at 400,000 pounds and draw a vertical line up to the 5 CBR curve, then horizontally to intersect with Line 1.
  - The point of intersection indicates an allowable pass number of approximately 750.
- In this example, the subgrade layer results in the lowest allowable number of passes. The maximum allowable number of C-17 passes at a gross weight of 400,000 pounds is 750.

6.1.4. Semi-prepared airfields may also be evaluated for various aircraft using the PCASE Unsurfaced Design (UNSURF) software program, *Computer Aided Evaluation of Expedient Airfields*. This program limits CBR inputs to two layers. Careful analysis of the DCP data is required to ensure that the layer data entered in the program represents the data determined in the field.

6.2. Flexible Pavement Surfaced Airfields. Flexible pavement systems may be evaluated manually using the flexible pavement evaluation curves in Appendix C.

6.2.1. Evaluation Procedures to Determine Allowable Passes.

6.2.1.1. Select the chart for the desired aircraft and traffic area from Appendix C.

6.2.1.2. Using the layer data from the PPD, enter the top of the chart with the thickness to the surface above the layer being evaluated. Follow downward to the appropriate gross weight curve, then horizontally to the curve corresponding to the CBR of the layer being evaluated. Then follow downward to determine the allowable number of aircraft passes.

6.2.1.3. Repeat this procedure for each soil layer. **The layer that produces the lowest allowable number of passes is the controlling layer for the evaluation.**

Example: Determine the allowable number of passes for a C-130 aircraft with a gross weight of 125 kilopounds (kips) on a Type A traffic area with the following flexible pavement profile:

- 5-inch asphalt surface course
- 6-inch base course, CBR 30
- 8-inch subbase course, CBR 15
- Subgrade, CBR 5

Solution:

- Select the Flexible Pavement Evaluation Allowable Passes, Type A Traffic Area, for the C-130 aircraft (Figure C-15). See Figure 27.
- Evaluate the base course. Enter the top of the chart at 5 inches (thickness of surface course) and follow downward to the 125 kips curve. Then follow horizontally to the 30 CBR curve and downward to determine the allowable passes: 10,000 for this layer.
- Evaluate the subbase course. Enter the top of the chart at 11 inches (thickness of surface and base courses combined) and follow downward to the 125 kips curve. Then follow horizontally to the 15 CBR curve and downward to determine the allowable passes: 20,000 for this layer.
- Evaluate the subgrade. Enter the top of the chart at 19 inches (thickness of surface, base, and subbase courses combined) and follow downward to the 125 kips curve. Then follow horizontally to the 5 CBR curve and downward to determine the allowable passes: 1,100 for this layer.
- In this example, the subgrade layer results in the lowest allowable pass rating. The maximum number of allowable passes for a C-130 aircraft at a gross weight of 125 kips is 1,100.

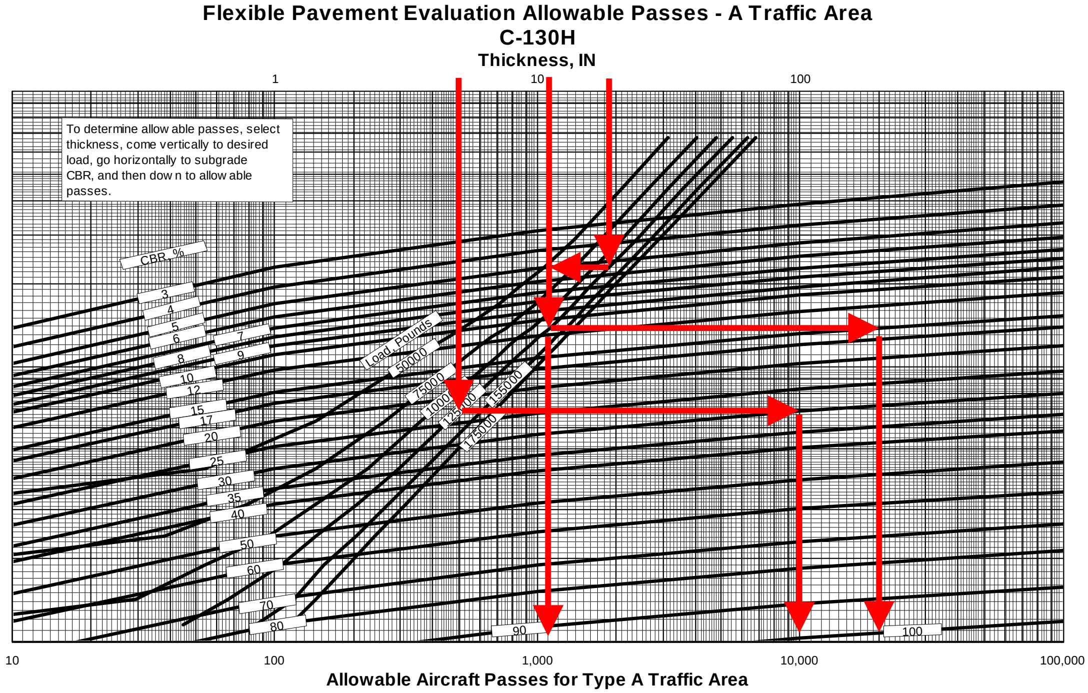


Figure 27. Example Evaluation of Flexible Pavement for Allowable Passes of C-130

6.2.2. Evaluation Procedures to Determine AGLs.

6.2.2.1. Select the chart for the desired aircraft and traffic area from Appendix C.

6.2.2.2. Using the layer data from the PPD, enter the top of the chart with the thickness to the surface above the layer being evaluated. Follow downward to the appropriate pass level curve, then horizontally to the curve corresponding to the CBR of the layer being evaluated. Then follow downward to determine the AGL of the aircraft.

6.2.2.3. Repeat this procedure for each soil layer. **The layer that produces the lowest AGL is the controlling layer for the evaluation.**

Example: Determine the allowable gross weight for 1,000 passes of a C-5 aircraft on a Type B traffic area with the following flexible pavement profile:

- 6-inch asphalt surface course
- 6-inch base course, CBR 60
- 12-inch subbase course, CBR 25
- Subgrade, CBR 6

Solution:

- Select the Flexible Pavement Evaluation Allowable Gross Load, Type B and C Traffic Areas, for the C-5 aircraft (Figure C-6). See Figure 28.
- Evaluate the base course. Enter the top of the chart at 6 inches (thickness of surface course) and follow downward to the 1,000-pass level curve. Then follow

horizontally to the 60 CBR curve. In this case, it falls off the chart to the right so the weight is not limited for this layer.

- Evaluate the subbase course. Enter the top of the chart at 12 inches (thickness of surface and base courses combined) and follow downward to the 1,000-pass level curve. Then follow horizontally to the 25 CBR curve and downward to determine the AGL: 1,010,000 pounds for this layer.
- Evaluate the subgrade. Enter the top of the chart at 24 inches (thickness of surface, base, and subbase courses combined) and follow downward to the 1,000-pass level curve. Then follow horizontally to the 6 CBR curve and downward to determine the AGL: 625,000 pounds for this layer.
- In this example, the subgrade layer results in the lowest AGL rating. The maximum allowable weight for 1,000 passes for a C-5 aircraft is 625,000 pounds.

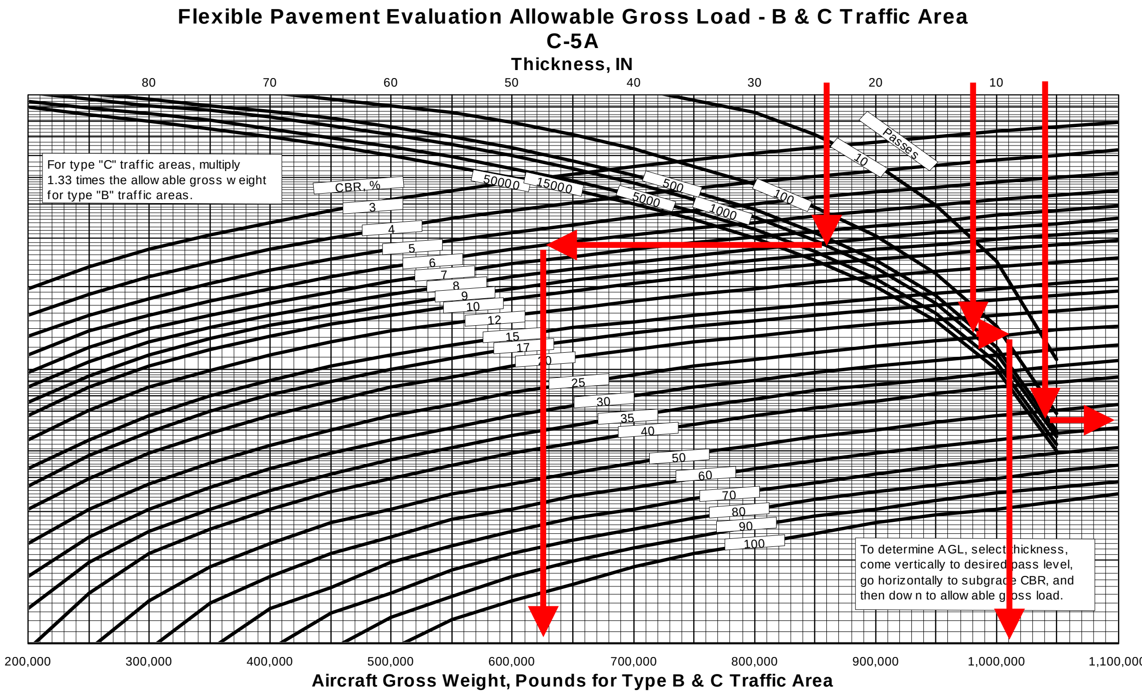


Figure 28. Example Evaluation of Flexible Pavement for AGL of C-5

6.2.3. Thickness Adjustments.

6.2.3.1. Minimum flexible pavement design requirements are shown in Table 11. When a pavement system has a surface or base course thickness that exceeds those requirements, the excess thickness is converted to equivalent subbase material, as shown in Table 10.

Table 10. Thickness Adjustments

Material	Equivalency Factors	
	Base	Subbase
Bituminous stabilized or all-bituminous concrete	1.15	2.30
GW, GP, GM, GC	1.00	2.00
SW, SP, SM, SC	0.75	1.50

Table 11. Minimum Design Thicknesses for Flexible Pavements

Airfield Type	Traffic Area	100 CBR Base		80 CBR Base	
		Surface	Base	Surface	Base
Light load (trainers)	A/B	4	6	5	6
	C	3	6	4	6
Medium load (C-5, C-17, C-141, KC-10, KC-135)	A/B	4	6	5	6
	C	3	6	4	6
Heavy load (B-52)	A	5	10	6	9
	B	4	9	6	8
	C	4	9	5	8
Modified heavy load (B-1)	A/B	5	8	6	8
	C	4	8	5	8
Shortfield (C-130)	A	4	6	5	6
Auxiliary (F-15, C-27)	A/B/C	3	6	3	6
	All Shoulders	2	6	2	6

6.2.3.2. These adjusted thicknesses are used to enter the appropriate evaluation charts. For example, a heavy load pavement with 8 inches of asphalt surface, 10 inches of CBR 100 base, and a 6-inch subbase has 3 inches more asphalt than required. The excess thickness of the surface course should be considered when calculating the depth of the subgrade. The subgrade should be evaluated with a 5-inch surface, 10-inch base, and 12.9-inch subbase (3-inch excess surface x 2.3 = 6.9 inches) or a 27.9-inch depth of cover in lieu of the measured 24 inches.

6.2.3.3. In contingency evaluations, the pavement thickness is often less than the minimum thickness prescribed in Table 11. In this case, evaluate the pavement cross-section as measured. This thinner pavement thickness will produce a reduced load-bearing capability, but, depending upon the intended mission, that capability may be sufficient. When very thin pavements are encountered, such as chip seal or DBST surfaces, and the concern is to facilitate the aircraft mission in lieu of preventing pavement damage, consider evaluating the pavement as unsurfaced and treating the surface as just a FOD sealer. The failure criteria used to evaluate unsurfaced pavement is less stringent than that for flexible surfaces and will often permit higher loads or more passes. If the concern is to prevent pavement damage, evaluate the structure as measured.

6.2.4. Pavement Condition Adjustments. If the cursory Pavement Condition Survey results in a feature condition rating of poor or lower, the maximum AGLs computed for that feature should be further reduced by 25 percent. If evaluating to determine allowable passes, multiply the gross weight by 1.33 to establish the correct gross aircraft weight curve to use in the chart.

6.2.5. Flexible pavement surfaced airfields may also be evaluated for various aircraft using the PCASE software programs.

6.3. Rigid Pavement Evaluation. Rigid or PCC-surfaced airfields may be evaluated manually using the rigid pavement evaluation and design factor curves in Appendix D. The curves can be used to determine AGLs or passes for a standard (first crack criteria) evaluation or extended life (shattered slab criteria) evaluation***.*** **The extended life curves are used for all Air Force pavement evaluation reports.**

6.3.1. Evaluation Procedures to Determine AGLs.

6.3.1.1. Select the rigid pavement evaluation curve for the desired aircraft from Appendix D to determine the load factor.

- Enter the chart with the thickness of the surface pavement, and then move horizontally to the K-value of the underlying soil. This K-value is the lowest effective K-value of all soil layers computed using Figure 18.
- Move vertically to the flexural strength. If data is not available on the flexural strength, use 700 for stateside bases or other areas where quality control is good and use 600 for contingency areas where quality control is uncertain.
- Move horizontally to read the load factor.

6.3.1.2. Select the design factor for extended life evaluation chart for the desired aircraft and traffic type from Appendix D to determine the design factor.

- Enter the chart with the number of passes.
- Move vertically up to the appropriate K-value line.
- Move horizontally to read the design factor.

6.3.1.3. Divide the load factor by the design factor to obtain the AGL.

Example: You are tasked to evaluate an apron feature at an airfield located in an undeveloped third-world country. You must determine the AGL for 10,000 passes of the C-141 aircraft. You core through the PCC pavement and determine it to be 11.5 inches thick. You perform DCP tests on the soil and discover a 12-inch layer with a 10 CBR beneath the pavement overlying a subgrade with a 3 CBR.

- 11.5-inch PCC surface course
- 12-inch base course, CBR 10
- Subgrade, CBR 3

Solution:

- The first step is to determine the values required to evaluate this cross-section.
  - From the number of passes (10,000), this is a sustainment or permanent evaluation, so the apron should be evaluated as a B traffic area (see paragraph 1.2.5).
  - The flexural strength of the PCC is not known, but because of the location you assume it is 600 psi (see paragraph 2.1.1).
  - The measured CBRs must be converted to K-values, and the K-values must be converted to effective K-values to determine the correct K-value to use to evaluate the pavement structure. The base course of 10 CBR converts to a K-value of 200 (see Figure 17) and because it is located immediately beneath the PCC, its effective K-value is also 200. The subgrade of 3 CBR converts to a K-value of 130 (see Figure 17). The 130 K-value with 12 inches of base course is converted an effective K-value of 225 (see Figure 18). Of the two layers, the base course yields the lowest effective K-value, 200, which should be used to evaluate the pavement structure (see paragraph 2.2.3.4).
  - The pavement structure values required for the evaluation are:
    - 11.5-inch PCC, Flex = 600 psi
    - Subgrade K-value = 200
- Select the rigid pavement evaluation load factor chart for the C-141 from Appendix D (Figure D-21). See Figure 29.
  - Enter the chart at 11.5 inches and move horizontally to the 200 k-value line.
  - Move vertically to the flexural strength of 600.
  - Move horizontally to read the load factor of 336,000.

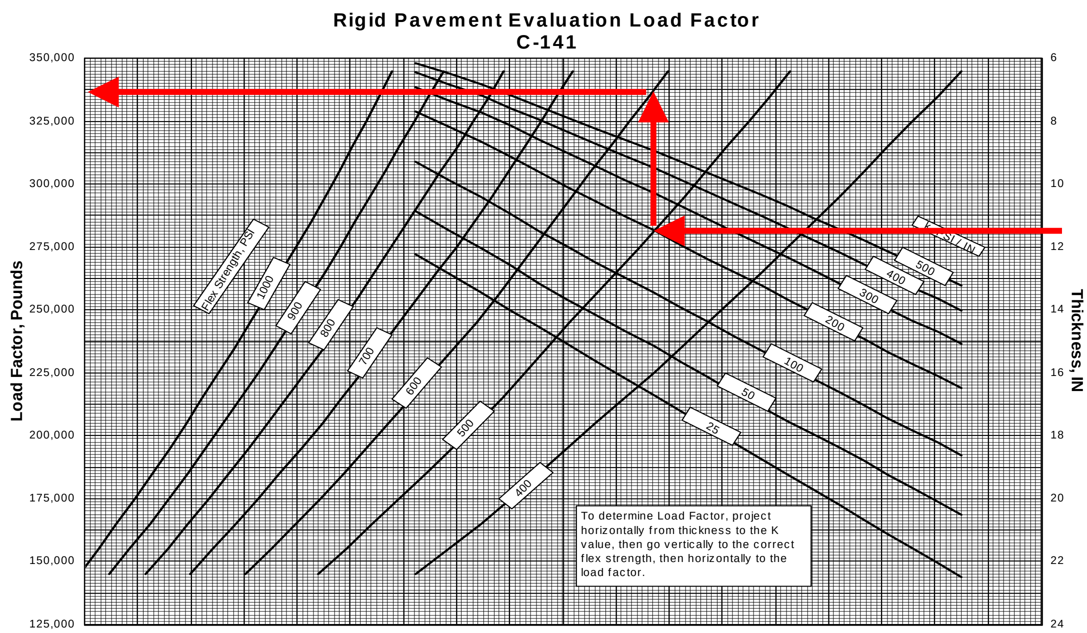


Figure 29. Example Determination of Load Factor in Evaluation of Rigid Pavement for C-141

- Select the design factor for extended life evaluation chart for the C-141, B traffic area, from Appendix D (Figure D-25). See Figure 30.

– Enter the chart at 10,000 passes and move vertically to the 200 K-value line for a B traffic area.
– Move horizontally to read the design factor of 1.05.
– Divide 336,000 by 1.05 to determine the AGL of 320,000.

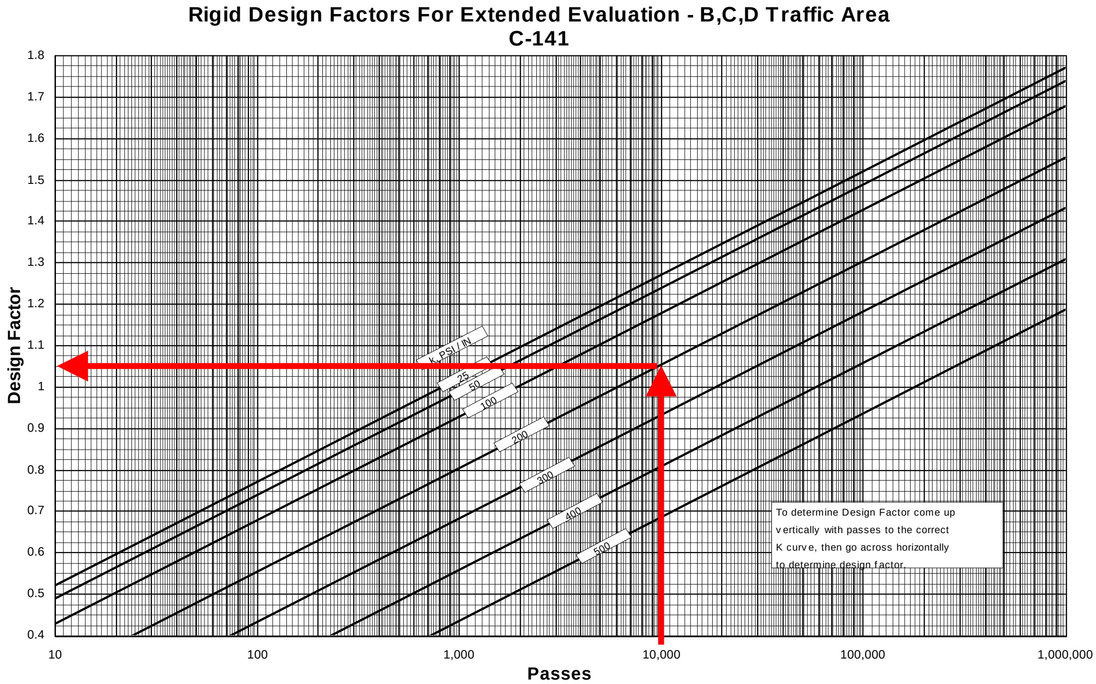


Figure 30. Example Determination of Design Factor in Evaluation of Rigid Pavement for C-141

6.3.2. Evaluation Procedures to Determine Allowable Passes:

6.3.2.1. Select the rigid pavement evaluation load factor chart for the appropriate aircraft from Appendix D and use the same procedures as used to evaluate for AGLs to determine the load factor.

6.3.2.2. Divide the load factor by the aircraft gross weight to determine the design factor.

6.3.2.3. Select the design factor for extended life evaluation chart for the appropriate aircraft and traffic type from Appendix D.

- Enter the chart at the determined design factor and move horizontally to the correct K-value line.
- Move vertically down to read the allowable number of passes.

Example: Determine the allowable number of passes for a C-5 aircraft with a gross weight of 650 kips on an A traffic area with the following rigid pavement cross-section:

- 9-inch PCC surface course, flex strength: 700 psi
- Subgrade, K = 100

Solution:

- Select the rigid pavement evaluation load factor chart for the C-5 from Appendix D (Figure D-6). See Figure 31.
  - Enter the chart at 9 inches and move horizontally to the 100 K-value line.
  - Move vertically down to the 700 flexural strength line and horizontally to determine the load factor of 720,000.

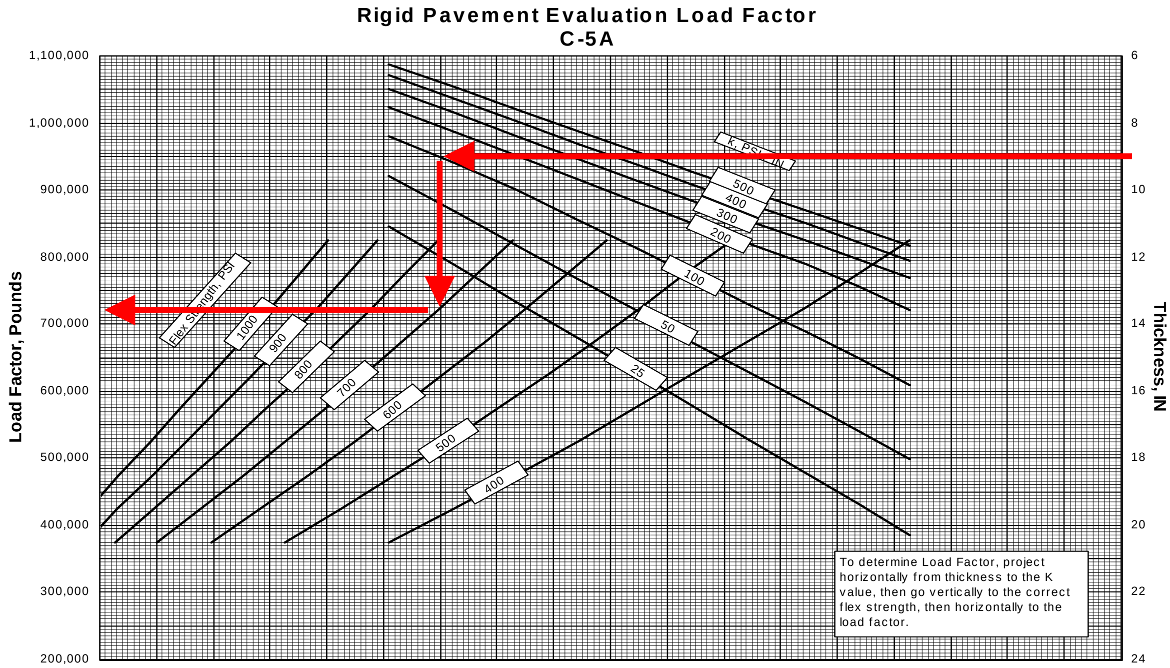


Figure 31. Example Determination of Load Factor in Evaluation of Rigid Pavement for C-5

- Select the design factor for extended life evaluation chart for the C-5, A traffic area, from Appendix D (Figure D-9). See Figure 32.
  - Enter the chart at the design factor of 1.11 and move horizontally to the 100 K-value line.
  - Move vertically down to determine the allowable pass number of 1,200.

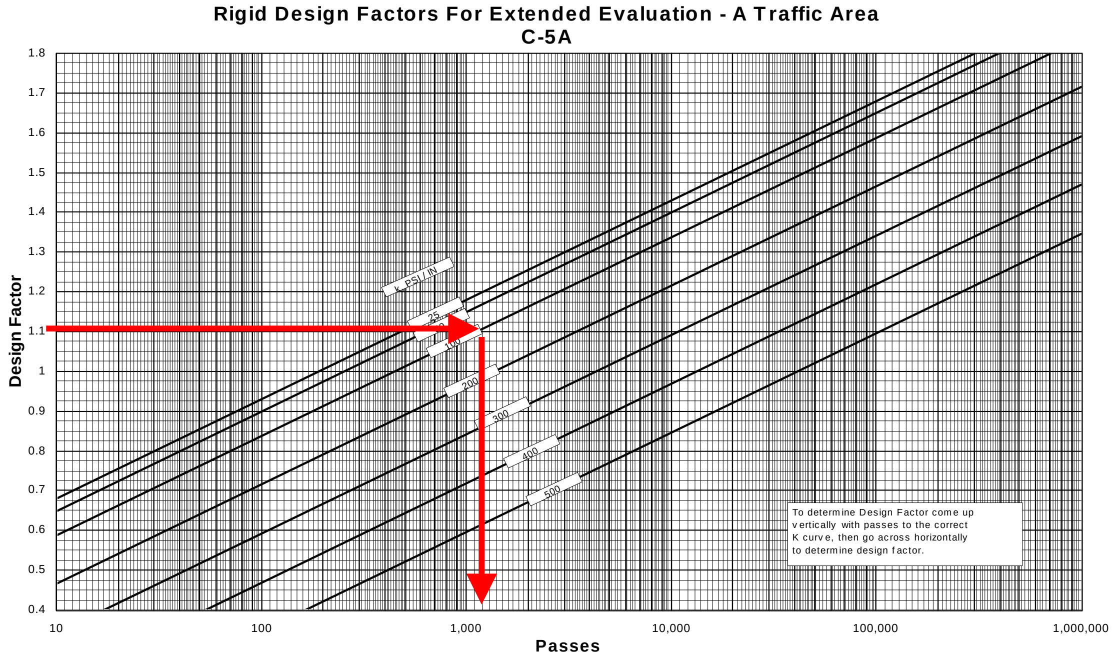


Figure 32. Example Determination of Allowable Passes in Evaluation of Rigid Pavement for C-5

6.3.3. Load Transfer. Rigid pavements are designed with the assumption that there is some transfer of load from the slab being loaded to those slabs adjacent to it. AGLs are reduced proportionally with reductions in load transfer. **When it is obvious that there is no load transfer, AGLs are reduced by 25 percent. Do not, however, take double deductions in load calculations; e.g., do not reduce AGLs by 25 percent because of the lack of load transfer and also reduce the AGLs by 25 percent because of poor surface condition.**

6.3.4. Reinforced Concrete Pavement. For evaluation of rigid pavements, do not assume the existence of reinforcing if you do not see it. Evaluate it as plain PCC pavement. If you know the pavement is reinforced, use the following steps to evaluate it:

6.3.4.1. Determine percent steel in a cross-section of rigid pavement. Compute the percent steel in both directions, by looking at the end area both transversely and longitudinally. If these are different, use the lowest percentage calculated.

$$\textbf{\% Steel = (AS/AP) x 100}$$

Where AS = Cross-sectional area of steel/foot of pavement width or length, expressed in square inches
AP = Cross-sectional area of pavement/foot of pavement width or length, expressed in square inches

6.3.4.2. Enter the bottom of Figure 33 with the thickness of the reinforced concrete, project a line vertically to intersect the calculated percent steel, and then project the line horizontally to determine the equivalent thickness of plain concrete pavement.

6.3.4.3. Using this equivalent thickness, evaluate the pavement as you would plain or unreinforced rigid pavement.

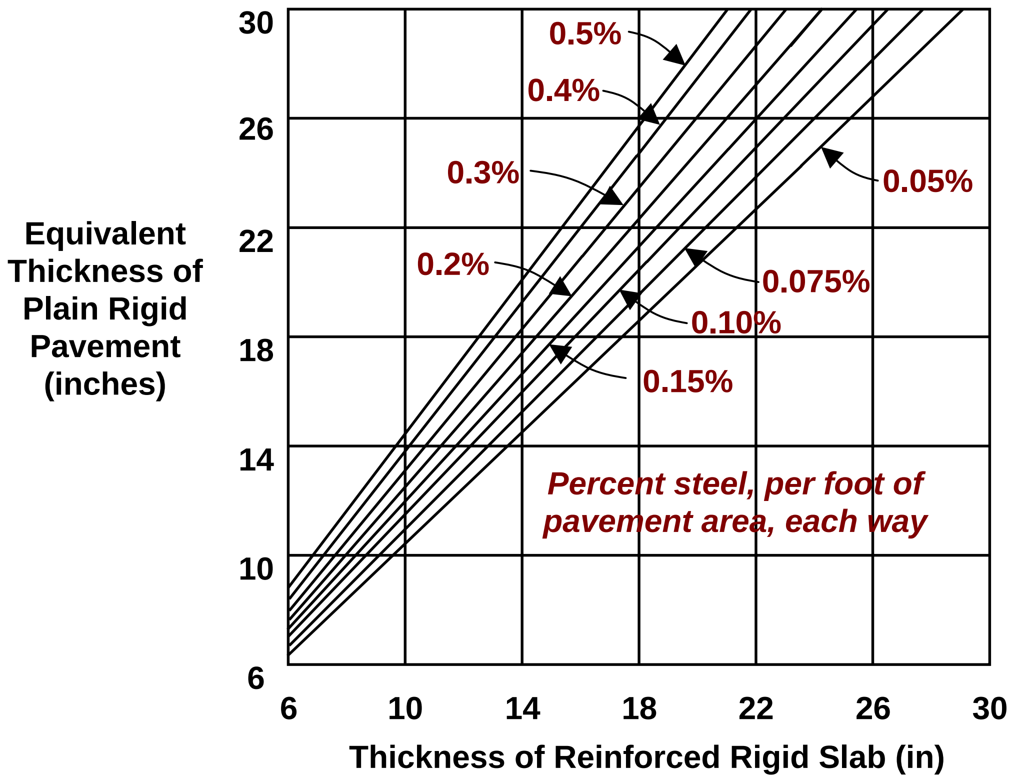


Figure 33. Reinforced to Plain Concrete, Equivalent Thickness

Example: Determine the equivalent thickness of plain PCC pavement to be used in lieu of 12-inch PCC pavement reinforced with 0.375-inch diameter bars both ways, spaced 6 inches apart.

Solution:

- Compute percent steel:
  (AS/AP) x 100 = (.221/144) x 100 = 0.153%
- Enter Figure 33 at 12 inches, project vertically to the 0.15% line, then horizontally to determine an equivalent thickness of 14.4 inches.

6.3.5. Other PCC Pavement Sections. If uncommon pavement sections, such as concrete pavers or precast slabs, are encountered on the airfield, contact HQ AFCESA for assistance.

6.4. Evaluating Overlays and Composite Pavements.

6.4.1. Rigid Overlay on Rigid Pavement.

6.4.1.1. Partially Bonded. If the rigid overlay was cast directly on the base slab with no sand, asphalt, or other material to break the bond with the base pavement, it should be evaluated as partially bonded (see Figure 34).

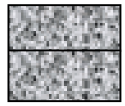


Figure 34. Rigid Overlay on Rigid Pavement

6.4.1.1.1. Compute the equivalent thickness (*H_E*) of the combined overlay section using the following equation:

$$H_E = \sqrt[1.4]{(H_O)^{1.4} + C_R(H_B)^{1.4}}$$

Where H_O = Thickness of rigid pavement overlay, inches
C_R= Coefficient representing condition of rigid base pavement (see Figure 35)
H_B = Thickness of rigid base pavement, inches
Recommended Values for C_R:
C_R = 1.00 for base pavement in good condition
C_R = 0.75 for base pavement having a few initial cracks due to loading, but no progressive cracks
C_R = 0.35 for badly cracked base pavement

6.4.1.1.2. To determine the condition rating of the base concrete, consider the purpose of the overlay. **In most cases where concrete is placed directly over existing concrete with no bond breaker, it is safe to assume the base concrete was in fairly good condition, provided that no structural distresses are noted on the surface. A C_R of 0.75 should be used.**

6.4.1.1.3. Evaluate as rigid pavement using the appropriate rigid pavement evaluation curve from Appendix D and entering the chart with the computed equivalent thickness, *H_E*.

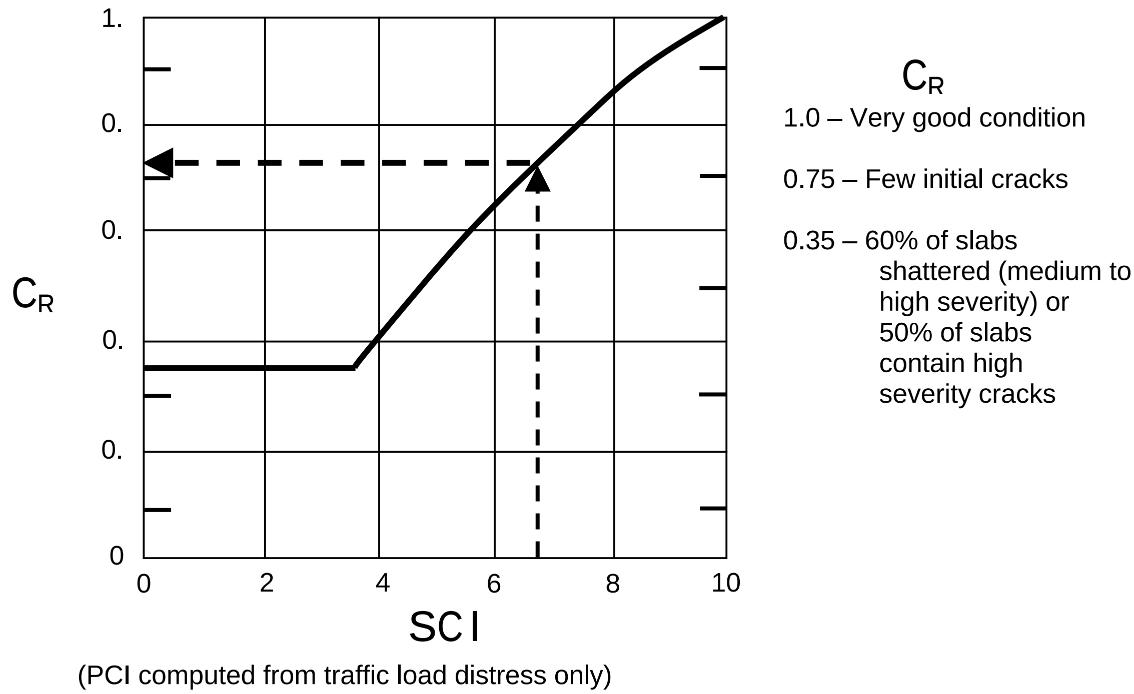


Figure 35. Condition Factor for Rigid Pavement Overlay

6.4.1.1.4. Compute the weighted average flexural strength for the evaluation using the following equation:

$$R = \frac{(H_O)(R_O) + (H_B)(R_B)}{H_O + H_B}$$

Where H_O = Thickness of rigid overlay
H_B = Thickness of rigid base slab
R_O = Flexural strength of rigid overlay
R_B = Flexural strength of rigid base slab

6.4.1.2. Unbonded, Bond Breaker Less Than 4 Inches.

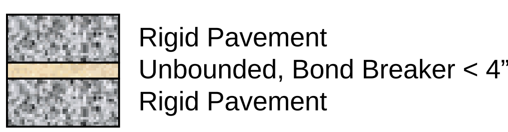


Figure 36. Unbonded Rigid Overlay on Rigid Pavement, Bond Breaker Less than 4 Inches

6.4.1.2.1. Compute the equivalent thickness, H_E of the combined overlay section using the following equation:

$$H_E = \sqrt{(H_O)^2 + C_R (H_B)^2}$$

6.4.1.2.2. To determine the condition rating of the base concrete, consider the purpose of the overlay. **Was the base concrete overlaid due to a mission change, which required increased pavement strength, or to correct surface distresses, such as those that produce FOD? If so, a C_R of 0.75 can be assumed. If the concrete was overlaid due to failure of the base pavement, or the reason is unknown, a lower C_R of 0.50 should be used.**

6.4.1.2.3. Compute the weighted average flexural strength for the evaluation using the equation in paragraph 6.4.1.1.1.

6.4.1.2.4. Evaluate as rigid pavement.

6.4.1.3. Unbonded, Bond Breaker Greater Than 4 Inches. Evaluate as composite pavement (paragraph 6.4.3).

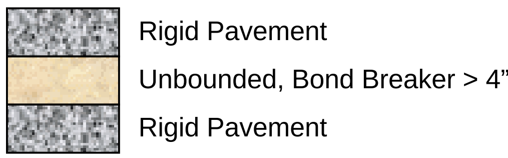


Figure 37. Unbonded Rigid Overlay on Rigid Pavement, Bond Breaker Greater than 4 Inches

6.4.2. Non-Rigid Overlay on Rigid Pavements. Evaluate as a rigid pavement system and as a flexible pavement system to determine which yields the higher AGLs or allowable passes. The higher AGLs or allowable passes should be reported in the evaluation.

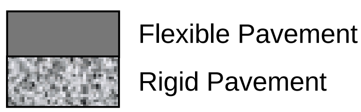


Figure 38. Flexible Overlay on Rigid Pavement

6.4.2.1. Evaluate as Rigid Pavement.

6.4.2.1.1. Compute the equivalent thickness (H_E) of the combined overlay section using the following equation:

$$H_E = \frac{1}{F}\left(0.33t + C_B(H_B)\right)$$

Where t = Thickness of nonrigid overlay pavement, inches
H_B = Thickness of rigid base pavement, inches
F = Factor which controls the degree of cracking in the rigid base pavement (see Appendix E)

6.4.2.1.2. For certain values of F, the equation will yield a H_E greater than the combined thickness of $H_B + t$. When this occurs, use the value of $H_B + t$ for H_E.

6.4.2.1.3. If a condition factor (C_B) for the base pavement is known, the thickness H_B would be multiplied by the condition factor to determine the equivalent thickness (see Figure 39).

6.4.2.1.4. To determine the condition rating of the base concrete, consider the purpose of the overlay and the condition of the surface. In all cases of AC overlays over concrete base materials, look for reflective cracking or other evidence of distresses in the base concrete. **If there are no reflective cracks (other than joint reflective cracks), a C_B of 0.80 should be used. If there are reflective cracks (other than joint reflective cracks), a C_B of 0.50 should be used.**

6.4.2.1.5. Evaluate as rigid pavement. If evaluating for the allowable number of passes, the process becomes interactive because the *F* factor is dependent on traffic level. **For expedient evaluations, assign an F factor of 0.80.**

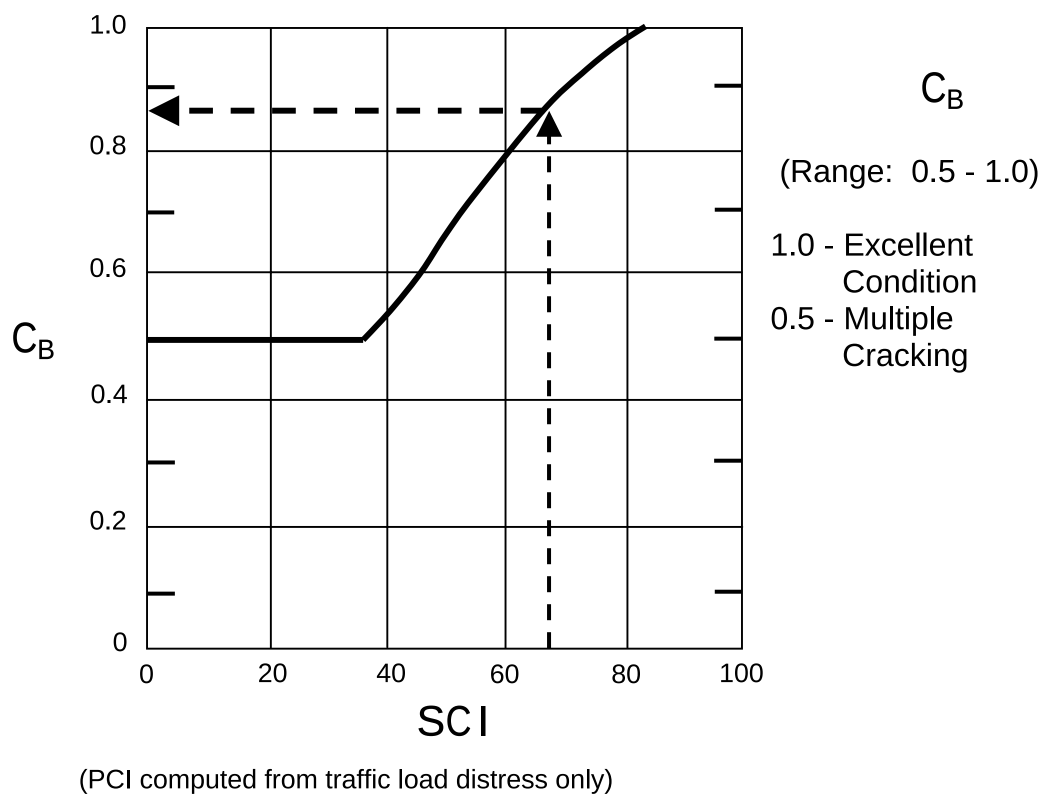


Figure 39. Condition Factor for Flexible Pavement Overlay

6.4.2.2. Evaluate as Flexible Pavement.

- Assume the nonrigid overlay is a flexible pavement.
- Assume the rigid base pavement is a high-quality base course material with a CBR of 100.
- Evaluate as flexible pavement.

6.4.3. Composite Pavements.

6.4.3.1. Bond Breaker Less Than 4 Inches.

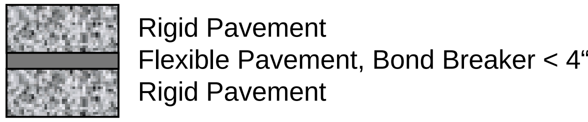


Figure 40. Rigid Overlay on Flexible Overlay on Rigid Pavement, Bond Breaker Less than 4 Inches

6.4.3.1.1. Evaluate as rigid overlay on a rigid pavement, with the thickness of the nonrigid material assumed to be a bond-breaking course.

6.4.3.1.2. Compute the equivalent thickness (H_E) of the combined overlay section using the following equation:

$$H_E = \sqrt{(H_O)^2 + C_R(H_B)^2}$$

6.4.3.1.3. Compute the weighted average flexural strength for the evaluation using the equation found in paragraph 6.4.1.1.1.

6.4.3.2. Bond Breaker Greater Than 4 Inches.

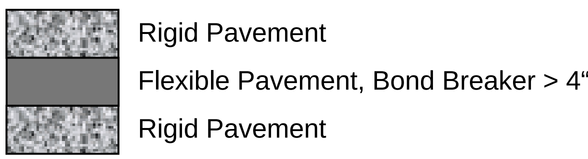


Figure 41. Rigid Overlay on Flexible Overlay on Rigid Pavement, Bond Breaker Greater than 4 Inches

6.4.3.2.1. Evaluate as rigid pavement, with the nonrigid material and the rigid base pavement assumed to be a base course.

6.4.3.2.2. The thickness of the rigid overlay and the flexural strength of the rigid overlay will be used in the evaluation.

6.4.3.2.3. In a normal evaluation a plate-bearing test would be performed on top of the nonrigid bond-breaker to establish the K-value. For contingency evaluations, this value must be estimated, based upon the thickness, confinement, and material type of the nonrigid bond-breaker. **If there are no surface structural distresses and the bond-breaker is gravel or a bituminous material, assign a 500 K-value. If there are no surface structural distresses and the bond-breaker is sand, assign a 400 K-value. If there are surface structural distresses, assign a 300 K-value.**

7. Determine Aircraft Classification Number/Pavement Classification Number (ACN/PCN). In 1983, the International Civil Aviation Organization (ICAO) developed and adopted a standardized method of reporting pavement strength. This procedure is known as the Aircraft Classification Number/Pavement Classification Number (ACN/PCN) method. The ACN is a number that expresses the effect an aircraft will have on a pavement system. The PCN is a number that expresses the capability of a pavement to support aircraft. Once AGLs are computed for each feature using the procedures in paragraph 6, they should be converted to PCNs. PCNs for a given feature will vary depending on which aircraft and number of passes they are based upon. **All routine reports generated by HQ AFCESA base the PCNs on the AGLs for the C-17 aircraft at 50,000 passes.** This facilitates pavement strength comparisons of bases throughout the Air Force. **For all evaluations, PCNs should be reported for the C-17 aircraft at a weight of 585,000 pounds for 50,000 passes.**

7.1. ACN/PCN Code. In the ACN/PCN method, the PCN, pavement type, subgrade strength category, tire pressure category, and evaluation method are reported together in a code system (see Table 12).

Table 12. ACN/PCN Code System

PCN	Pavement Type	Subgrade Strength	Tire Pressure	Method of PCN Determination
Numerical Value	R=Rigid F=Flexible	A=High B=Medium C=Low D=Ultralow	W=High X=Medium Y=Low Z=Ultralow	T=Technical Evaluation U=Using Aircraft

Subgrade Strength Code	Flexible Pavement (CBR)	Rigid Pavement (k)
A	Over 13	Over 400
B	8 - 13	201 - 400
C	4 - 8	100 - 200
D	< 4	< 100

Tire Pressure Code	(PSI)
W	No Limit
X	146 - 217
Y	74 - 145
Z	0 - 73

Example: If the reported PCN for a feature is **42/R/C/W/T**, “**42**” indicates the PCN number, “**R**” indicates that it is a rigid or PCC surface, “**C**” indicates a low subgrade strength, “**W**” indicates that high tire pressures are allowed, and “**T**” indicates that a technical evaluation was performed to determine the PCN. Each part of the code is important. The number “**42**” cannot be used properly without the letters that follow.

7.1.1. The pavement type reported is determined by the method of evaluation, not the surface type. For example, if a rigid (concrete) pavement with a flexible (asphalt) overlay was evaluated as a rigid pavement, the pavement type in the PCN should be reported as R.

7.1.2. In PCN instructions, the term “subgrade” refers to all soil beneath the pavement, not just the in-situ soil at the bottom of a typical flexible pavement cross-section. **When reporting the subgrade strength code, the strength of the critical or controlling layer in the evaluation should be used.** For flexible pavements, this should be based upon the CBR of the controlling layer. For rigid pavements, it should be based upon the effective K-value used in the evaluation.

7.2. ACN values for particular aircraft are determined the same way as PCN values because they are relative to the aircraft load, pavement type, and subgrade strength. An ACN may be determined for any combination of pavement type, subgrade category, and aircraft weight using the ACN/PCN charts in Appendix F. The ACN numbers for a given aircraft vary with the pavement type and subgrade strength category, as shown by the eight possible ACN values for a 345,000-pound C-141 aircraft:

Rigid Pavement	Flexible Pavement
50/R/A	52/F/A
61/R/B	61/F/B
68/R/C	68/F/C
73/R/D	80/F/D

The ACN of a 345,000-pound C-141 varies on rigid pavement from 50 to 73 depending upon the subgrade strength and similarly varies on flexible pavement. For lower aircraft weights, the ACNs would be lower. When analyzing the effect of an aircraft on a specific pavement feature, the appropriate ACN must be selected. For example, if the PCN of a given feature is 74/R/B/W/T, to determine the effect of a 345,000-pound C-141 on the feature, the correct ACN to compare with the PCN is 61/R/B (the one considering similar pavement type and subgrade strength).

7.3. The ACN/PCN system is structured so that a pavement with a particular PCN value can support an aircraft that has an ACN value equal to or less than the PCN. If the ACN is more than the PCN, the pavement will be overloaded and the pavement life reduced. Except for massive overloading, pavements are not subject to a limiting load above which they suddenly or catastrophically fail. Occasional minor overloading is therefore acceptable and there will be situations when operators decide to overload the pavement (e.g., emergency landings, short-term contingencies, exercises, and air shows). As a general guide:

- ACN/PCN ratios of up to 1.1 have minimal impact on the pavement life.
- When there is concern to minimize pavement damage, and the ACN/PCN ratio is between 1.1 and 1.4, aircraft operations should be limited to 10 passes and the pavement should be inspected after each operation.
- When there is concern to minimize pavement damage, and the ACN/PCN ratio exceeds 1.4, aircraft operations should not be allowed except in emergencies.
- Overload movements should not be allowed on pavements exhibiting signs of structural distresses or failure.
- In frost-susceptible regions, overloading should be avoided during periods of thaw or when the subgrade appears weakened.
- For seasonally wet regions, overloading should be avoided if the subgrade appears saturated or weakened by water.
- **For expedient evaluations, and sustainment evaluations where aircraft missions are the primary concern, do not restrict aircraft operations just because the ACN/PCN ratio exceeds 1.1. Evaluate the airfield capability based upon mission requirements and computed allowable pass levels.**

7.4. A word of caution: the ACN/PCN system was developed to compare the impact of various aircraft operations on a given pavement structure, **but the aircraft used to determine the pavement PCN has an impact on the PCN value. Using different aircraft and pass levels to determine the PCNs will result in different PCN values.** Not all evaluations in DOD produce PCNs that are based upon 50,000 passes of a C-17. Other agencies, foreign and domestic, base the PCNs on the using aircraft type and traffic. **In situations where the basis for a reported PCN is not known, an effort should be made to perform the necessary field tests to determine AGLs or allowable passes before making a decision on mission capability.**

7.5. If means are not available to measure soil strength and assign an appropriate subgrade strength code to the PCN, the following assumptions can be used if soil classification is known:

Subgrade Code	Unified Classification
A – High	GW, GP, GM
B – Medium	GC, SW, SP, SM
C – Low	SC, OL, CL, ML
D – Ultra Low	OH, CH, MH

7.6. To determine the reportable PCN for a given feature, select the C-17 ACN/PCN chart for the type pavement surface being evaluated (Appendix F), enter the chart at the allowable gross weight calculated for the C-17 at 50,000 passes, project vertically to intersect the correct subgrade strength line, then horizontally to read the resulting PCN. For example, if the allowable weight for the C-17 at 50,000 passes on a flexible pavement with a controlling subgrade strength of 10 CBR is calculated at 520,000 pounds, the reported PCN would be 49F/B/W/T. See Figure 42.

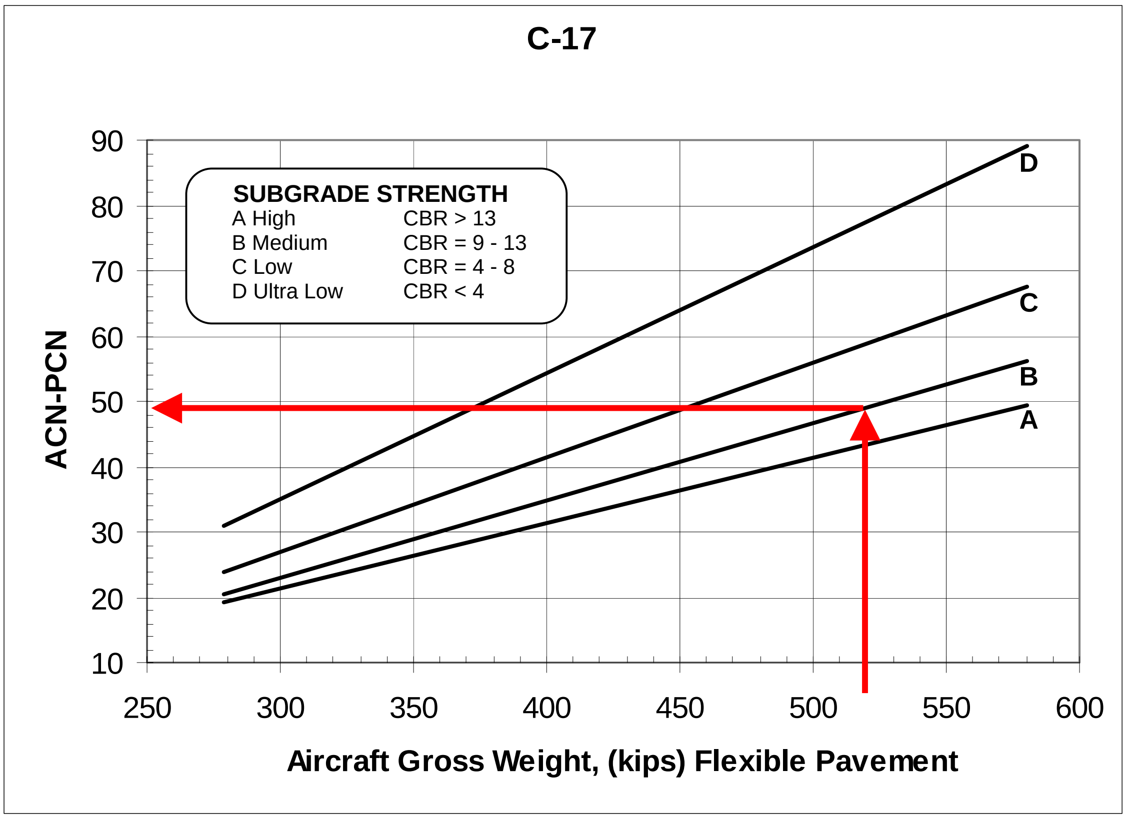


Figure 42. Example PCN Chart

7.7. Many nations continue to use the load classification number (LCN) method to report pavement capability. This was a standard method used before the adoption of the ACN/PCN system. The Air Force is familiar with the LCN system and uses it. **The LCN should be used for evaluation purposes only when more detailed information is not available.** Figures 43 and 44 contain approximate conversions from LCNs to PCNs. LCNs were based upon the stress developed in several standard PCC slab/base course structures and do not correlate well for all pavement types. When comparing LCNs to AGL computations for various pavements, consider the following:

- Single-wheel aircraft on rigid pavement – compares fairly well.
- Multi-wheel aircraft on rigid pavement – results are variable depending upon how the actual pavement structure compares to the standard LCN structures.
- Single-wheel aircraft on flexible pavement – results are more variable because the rigid pavement criterion was used to compute the flexible pavement stresses.
- Multi-wheel aircraft on flexible pavement – results will vary considerably.
- The LCN system assumes that all base course materials in the flexible pavement structure met and still meet the original design specifications (e.g., CBRs, gradations).

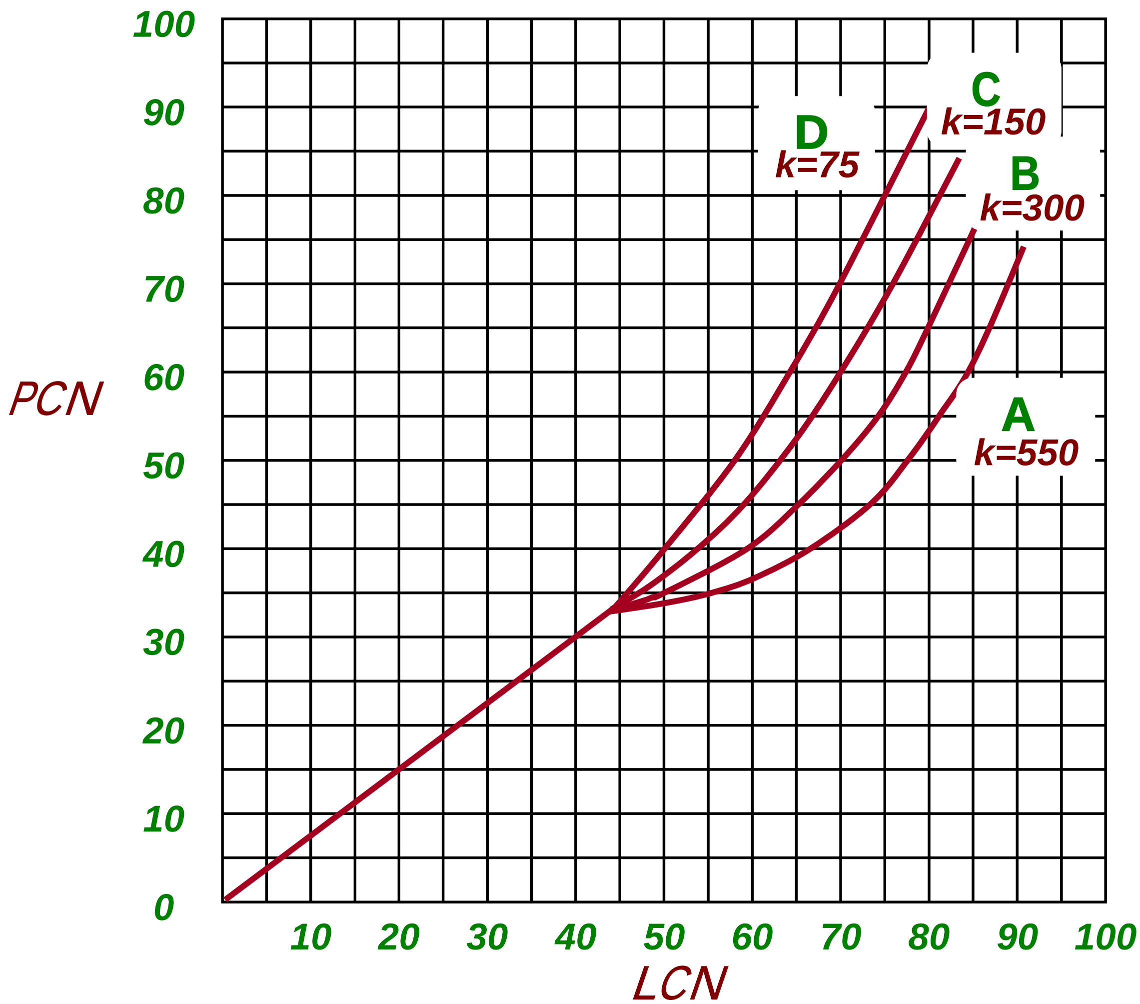


Figure 43. LCN to PCN Conversion, Rigid Pavement

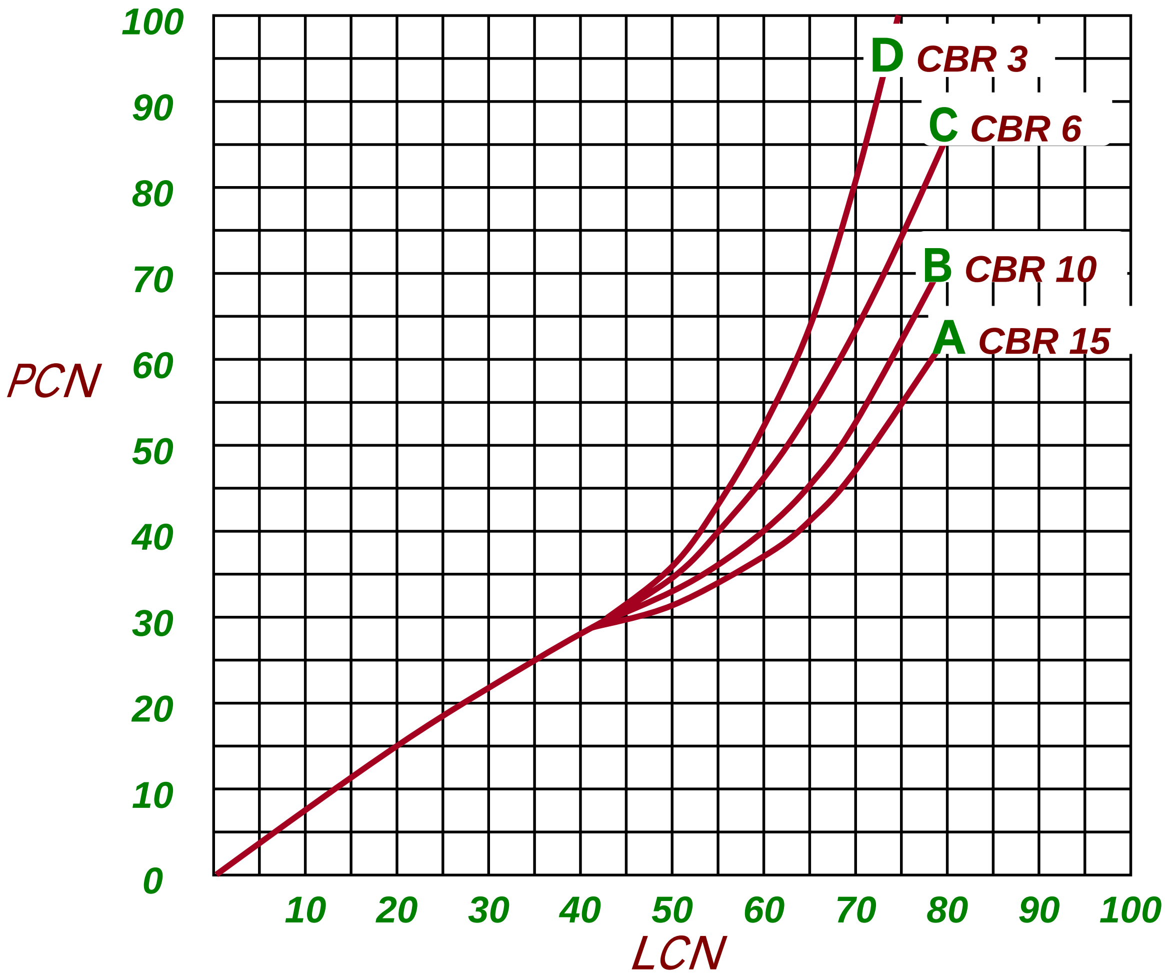


Figure 44. LCN to PCN Conversion, Flexible Pavement

8. Evaluation Report.

8.1. Once the field testing and data analysis are complete, the results should be published in a format that is easily understood. Reports for expedient evaluations vary from those published for sustainment and permanent evaluations.

8.1.1. Expedient evaluation reports should contain the following minimum information:

8.1.1.1. Summary. Include the following:

- Location and dates of evaluation.
- Requester.
- Answers to the questions that prompted the evaluation.
- Mission capability. Provide text or tables as needed to summarize report findings in terms of structural load-bearing capability (allowable aircraft operations or allowable gross weight limitations). At a minimum, provide the allowable passes for the mission aircraft at its maximum weight, along with allowable passes or AGLs for other aircraft as requested by the tasking agency/agencies.

- Provide PCNs for each area evaluated based upon 50,000 passes of the C-17 at 585,000 pounds. **Note the governing or controlling PCN, which is defined as the weakest feature along the central portion (75-foot keel) of a runway from threshold to threshold. It also includes the entire width of the touch-down zones.** Overruns and the non-keel pavements of the runway interior are excluded under this definition.

8.1.1.2. Observations. Include the following:
- Description of pavement surface condition, to include the PCI rating and discussion of major distresses. **Document the condition ratings with photographs.**
- Description of any limiting factors that may impact aircraft operations, such as craters, high-severity distresses, obvious obstructions, or weak areas.
- Explanation of areas that are closed to or restrict aircraft ground operations.

8.1.1.3. Analysis. Include the following:
- PPD Sheet listing all the test locations shown on the scaled drawing, with the cross-sectional data that was used to evaluate that location. Sources of the reported data should also be documented as notes on this sheet.
- Explanation of data included in the PPD, as required.
- **Document all assumptions used in the evaluation process and the rationale for any deviations from the recommended assumptions in this publication.**

8.1.1.4. Airfield Layout. Scaled drawing of the airfield, showing:
- Runway length and width.
- Names for other operational surfaces (e.g., Taxiway C, North Apron).
- Highlighted areas that are closed to or restrict aircraft ground operations.
- Test locations.
- Areas of major repair, weak areas, and crater repairs.
- Pavement surface types.

8.1.1.5. Evaluation team members. Include the following:
- Name(s).
- Organization(s).
- Phone number(s).
- E-mail address(es).

8.1.2. Copies of all expedient evaluation reports should be distributed to HQ AFCESA and the tasking agency/agencies as required.

8.1.3. Appendix G is an example expedient evaluation report that may be useful as “boiler plate” for expedient evaluation reports.

8.2. Sustainment and permanent evaluation reports should include the same information as an expedient evaluation, but in greater detail. Information should be provided for each feature evaluated. Much of the information, because of quantity, is best summarized in tables as well as descriptions located in the text of the report; plans are also more detailed.

Glossary

Aircraft Classification Number (ACN): A number that expresses the relative structural effect of an aircraft on different pavement types for specified standard subgrade strengths in terms of a standard single-wheel load. The ACN is numerically defined as twice the derived single wheel load (expressed in thousands of kilograms) at a standard tire pressure of 181 psi, which requires the same pavement thickness as the actual main gear of the aircraft for a given limiting stress or number of load repetitions.

Airfield Cone Penetrometer (ACP): Probe-type field-expedient instrument that gives an index of soil strength, in terms of an Airfield Index (AI). This AI can then be used to estimate a CBR value.

Airfield Index (AI): A numerical reading, ranging from 1 to 15 (CBR 1 to 18), taken from an airfield cone penetrometer indicating the strength of fine-grained soils.

Allowable Gross Load (AGL): The load on the critical aircraft that can be supported by the pavement for the desired number of passes.

Allowable Passes*:* The number of passes of an aircraft operating at a specific weight that the pavement will support before failure.

Base or Subbase Courses*:* Natural or processed materials placed on the subgrade beneath the pavement.

California Bearing Ratio (CBR): An empirical measure of soil strength used in the conventional design and evaluation of flexible pavement and unsurfaced airfields. To determine a CBR, a dynamic load is applied to a piston whose end is 3 square inches in area, forcing it to penetrate the soil at a rate of 0.05 inch/minute. The load required in pounds per square inch (psi) to force penetration gives the modulus of shear that is converted to a CBR using established load factors. Penetration into a crushed well-graded limestone serves as the benchmark material with a CBR of 100.

Channelized Traffic: Traffic distribution, or pass-to-coverage ratio, is primarily a function of tire width and allowable lateral wander. Channelized traffic areas are those where the aircraft traffic is concentrated in a narrow path with limited (70 inches wide) wander. 'A' traffic areas are designed for channelized traffic.

Compacted Subgrade*:* The upper part of the subgrade, which is compacted to a density greater than the portion of the subgrade below.

Composite Pavement: A "sandwich pavement" consisting of a rigid pavement overlay placed on top of an existing pavement consisting of a nonrigid overlay on a rigid pavement base. The nonrigid overlay may be bituminous pavement for its full depth or a combination of bituminous pavement and granular material.

Coverage: This term has different meanings for rigid and flexible pavements. For rigid pavements, coverage is a measure of the number of maximum stress applications that occur within the pavement due to the applied traffic. A coverage occurs when each point in the pavement within the limits of the traffic lane has been subjected to maximum stress. For flexible pavements, coverage is a measure of the number of maximum stress applications that occur on the surface of the pavement due to the applied traffic. A coverage occurs when all points on the pavement surface within the traffic lane have been subjected to one application of maximum stress. Thus, a twin-tandem gear would produce two applications of stress on the surface of a flexible pavement, but it would produce only one maximum stress application within a rigid pavement if the tandem spacing was small and would produce two maximum stresses if the tandem spacing was large.

DCP Index: A ratio of the depth of penetration per each hammer blow of the dynamic cone penetrometer (DCP), indicating the strength of soils. This DCP index can be correlated to a CBR value.

Double Bituminous Surface Treatment (DBST): A thin bituminous surface course, often found on less-trafficked areas such as overruns, consisting of a layer of uniform graded stone covered with a layer of bituminous emulsion, followed by a second layer of smaller size uniform graded stone and covered by another bituminous layer.

Dynamic Cone Penetrometer (DCP): A probe-type instrument consisting of a cone-tipped rod that is driven into the soil by a sliding hammer. The DCP provides an indication of soil strength in terms of a DCP index.

Effective K-value: Rigid pavements are evaluated using the K-value or index of the support provided by the soil immediately beneath the concrete slab. Often, K-values are measured directly on subgrade materials that may then be covered by granular base or drainage layer materials before placing the surface slab. These intermediate layers between the subgrade and the slab provide additional support. The measured K-value of a subsurface layer is converted to an effective K-value based upon the thickness of the intermediate layers to take into account the additional support they provide.

Equivalent Single Wheel Load (ESWL): The load on a single wheel with the same contact radius as the gear wheels that will produce the same maximum deflection as the whole gear assembly and at a specified depth within the pavement structure.

Expedient Evaluation: Assessment of airfield structural capability to support 100 passes of a particular aircraft at its maximum weight or the number of passes to support the initial surge of mission aircraft.

Failure Criteria: Condition or degree of distress used in pavement design to identify when a pavement structure has reached its end-of-life or terminal condition, which is referred to as "failure."

> ***Flexible Pavement Failure:*** A 1-inch rut, measured on the surface, including both the permanent deformation and surface upheaval, but may be caused by failure of any layer within the pavement structure. A flexible pavement may also be considered functionally failed if surface cracking destroys the waterproofing provided by the bituminous surface.
>
> ***Rigid Pavement Failure:*** Air Force evaluations are based upon extended-life criteria where 50 percent of the slabs are cracked into approximately six pieces at the end of traffic. This is also referred to as "shattered slab failure." Army evaluations are based upon standard life criteria where 50 percent of the slabs are cracked into two or more pieces at the end of traffic. This is also referred to as "initial failure" or "first crack failure."

Semi-prepared Surface Failure: A 3-inch rut, measured on the surface, including both the permanent deformation and surface upheaval, but may be caused by failure of any layer within the pavement structure.

Feature: A unique portion of the airfield pavement distinguished by traffic area, pavement type, pavement surface thickness and strength, soil layer thickness and strength, construction period, and surface condition.

Flexible Pavement: A pavement with a bituminous surface course and one or more supporting base or subbase courses placed over a prepared subgrade.

Flexural Strength: For Portland cement concrete (PCC), the breaking strength of a simply supported beam that is subjected to vertical loading. Also known as the modulus of rupture, it approximates the tensile strength of the concrete.

Frost Area Index of Reaction (FAIR): An index of soil strength used in lieu of a K-value to evaluate rigid pavement during thaw-weakened periods.

Frost Area Soil Support Index (FASSI): An index of soil strength used in lieu of a CBR to evaluate flexible pavement during thaw-weakened periods.

K-value (Modulus of Subgrade Reaction): An index used to rate the support provided by a soil layer beneath a concrete (PCC) slab. A K-value is determined during a plate-bearing test by placing an incrementally increasing load on a set of stacked plates and measuring the resulting deflection of the bottom plate. This deflection is corrected for load deformation and plate bending to determine the actual volume of soil displaced under load. The K-value is the proportion of the applied load or vertical stress to the area of deformation and is expressed in pounds per square inch, per inch of deformation, or PCI.

Landing Zone (LZ): A paved or semi-prepared airfield used to conduct operations in an airfield environment similar to forward operating locations.

Load Classification Number (LCN): A number expressing the relative effect of an aircraft on a pavement system or the bearing strength of a pavement.

Non-channelized Traffic: Traffic distribution, or pass-to-coverage ratio, is primarily a function of tire width and allowable lateral wander. Non-channelized traffic areas are those where the aircraft traffic is concentrated in a broader path with less limited (140 inches wide) wander. B and C traffic areas are designed for non-channelized traffic.

Passes: The number of aircraft movements across an imaginary transverse line placed within 500 feet of the end of the runway. For taxiways and aprons, passes are determined by the number of aircraft movements across a line on the primary taxiway that connects the runway and parking apron.

Pass/Coverage Ratio: The number of passes of a particular aircraft required to produce one coverage of the traffic lane. This is primarily a function of tire width and allowable lateral wander. This number is different for each aircraft due to gear configurations and also varies for rigid and flexible pavement because of the way the loads are distributed in the pavement.

Pavement Classification Number (PCN): A number that expresses the relative load-carrying capability of a pavement in terms of a standard single-wheel load.

Pavement-Transportation Computer Aided Structural Engineering (PCASE): A collection of road, airfield, and railroad design and evaluation computer software programs developed by the U.S. Army Corps of Engineers (USACE), written using current USACE criteria and technology.

Pavement Condition Index (PCI): A numerical rating resulting from an airfield condition survey that represents the severity of surface distresses.

Permanent Evaluation: Assessment of airfield structural capability to support long-term aircraft operations—generally 50,000 passes or more of a particular aircraft at its maximum weight. The results of a permanent evaluation may also be presented as an AGL table that depicts the airfield load-bearing capability in terms of multiple aircraft, divided into 14 aircraft groups.

Rigid Pavement: A pavement consisting of a nonreinforced Portland cement concrete (PCC) surface course resting directly on a prepared subgrade, granular base course, or stabilized layer.

Semi-prepared Airfield: An airfield without a paved (rigid or flexible) surface. The surface may be aggregate, unsurfaced, or stabilized material. The structure typically consists of three layers: the existing subgrade, a subbase, and a base or surface course. A semi-prepared airfield may or may not have a subbase or a base. If the existing material (the subgrade) is determined to be capable of supporting aircraft operations, no subbase or base will be required.

Structural Condition Index (SCI): A numerical rating resulting from an airfield condition survey that is calculated based only upon structural or load-related pavement distresses.

Subgrade*:* The natural in-place soil upon which a pavement, base, or subbase course is constructed.

Sustainment Evaluation: Assessment of airfield structural capability to support sustained aircraft operations—generally 5,000 passes of a particular aircraft at its maximum weight, or the number of passes required to support the mission aircraft throughout the anticipated operation.

Type A Traffic Area: Area of the airfield designed to support full or maximum weight of the aircraft, with channelized traffic.

Type B Traffic Area: Area of the airfield designed to support full or maximum weight of the aircraft, with non-channelized traffic.

Type C Traffic Area: Area of the airfield designed to support a reduced (75 percent of maximum) weight of the aircraft, with non-channelized traffic.

Unified Soil Classification System (USCS): System developed by the U.S. Army Corps of Engineers (USACE) to group or classify soils based upon particle size, gradation, and plasticity characteristics, and rates their suitability as airfield construction materials.

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Appendix A: Soil Characteristics

A.1. Soil Properties. The physical properties of a soil aid in determining the soil's engineering characteristics. These properties are the basis for the system of soil classification used in engineering identification of soil types. Physical characteristics of soil particles are size and shape. The proportions of particles of different sizes determine the gradation of the aggregate. Compactness refers to the closeness of packing of the soil particles—the closer the packing, the greater the compactness, and the larger the weight of the soil per unit of volume. Plasticity characteristics of fine-grained soil components influence bearing capacity. The presence of organic matter is important to the engineering use of soils. Color, texture, odor, structure, and consistency are readily observed factors that aid in soil description.

A.1.1. Grain-Size Groups. Soils are divided into groups based on the size of the particle grains in the soil mass. Size groups in the USCS are shown in Table A-1. Coarse-grained soil particles that fall into the gravel or sand groups are individually discernible to the naked eye—fine-grained soil particles are not. In the fine particle group, particles passing the No. 200 sieve, but larger than 0.002 to 0.005 millimeter are called silt. Those finer are called clay.

Table A-1. Soil Grain Size Groups

Size Group	Passing	Retained On	Example
Boulders	No maximum size	12 inch	
Cobbles	12 inch	3 inch	
Gravels	3 inch	No. 4	Lemon to pea
(Coarse)	3 inch	0.75 inch	Lemon to walnut
(Fine)	0.75 inch	No. 4	Walnut to pea
Sands	No. 4	No. 200	Pea to powdered sugar
(Coarse)	No. 4	No. 10	Pea to rock salt
(Medium)	No. 10	No. 40	Rock salt to table salt
(Fine)	No. 40	No. 200	Table salt to powdered sugar
Fines	No. 200	No minimum size	

A.1.2. Particle Shape. The shape of particles influences the strength and stability of a soil. Two general shapes are normally recognized: bulky and platy. The bulky shapes include particles that are relatively equal in all three dimensions. In platy shapes, one dimension is very small compared to the other two. Bulky shapes are subdivided depending on the amount of weathering that has acted on them. They may be angular, subangular, subrounded, or rounded. The angular shape shows flat surfaces, jagged projections, and sharp ridges. The rounded shape has smooth curved surfaces and is almost spherical. Cobbles, gravels, sand, and silt fall into the bulky shape group. Particles of clay soil exhibit a platy shape, though too small to be seen with the naked eye.

A.1.3. Soil Gradation. The size and shape of the soil particles deal with properties of the individual grains in a soil mass. Gradation describes the distribution of the different size groups within a soil sample. The soil may be well graded or poorly graded.

A.1.3.1. Well-graded soils must have a good range of all representative particle sizes between the largest and the smallest. All sizes are represented, and no one size is either overabundant or missing.

A.1.3.2. Poorly-graded soils are either those containing a narrow range of particle sizes or those lacking some intermediate sizes. Soils with a limited range of particle sizes are called uniformly graded. Soils which have some intermediate size or sizes not well represented or missing are called gap graded, step graded, or skip graded.

A.1.4. Compactness. The structure of the aggregate of soil particles may be dense (closely packed) or loose (lacking compactness). A dense structure provides interlocking of particles with smaller grains filling the voids between the larger particles. When each particle is closely surrounded by other particles, the grain-to-grain contacts are increased, the tendency for displacement of individual grains under load is lessened, and the soil is capable of supporting heavier loads. Coarse materials that are well graded are usually dense and have strength and stability under load. Loose, open structures have large voids and will compact under load, leading to settlement or disintegration under foundation or traffic loads. The shape of the grains also affects the bearing capacity. Angular particles tend to interlock and form a dense mass, and are more stable than the rounded particles that can roll or slide past one another.

A.1.5. Moisture. The moisture content of a soil mass is often the most important factor affecting the engineering behavior of the soil. The water may enter from the surface or may move through the subsurface layers either by gravitational pull, capillary action, or hygroscopic action. This moisture influences various soils differently and usually has its greatest effect on the behavior of fine-grained soils such as silts and clays. The term “moisture content” (w) is used to define the amount of water present in a soil sample. It is the proportion of the weight of water to the weight of the solid mineral grains (weight of dry soil) expressed as a percentage.

$$\%W = {}^{\text{wt of water}}/_{\text{wt of dry soil}} \times 100$$

Grain size affects soil moisture. Coarse-grained soils with larger voids permit easy drainage of water. They are less susceptible to capillary action. The amount of water held in these soils is less than in fine-grained soils, since the surface area is smaller and excess water will tend to drain off whenever possible. The fine grains and their small voids retard the movement of water and also tend to hold the water by surface tension. Clay soil properties may vary from essentially liquid to almost brick-hard with different amounts of moisture. Furthermore, clays are basically impervious to the passage of free or capillary moisture.

A.1.6. Cohesive Soils. A cohesive soil has considerable strength when air-dried, but has low strength when its moisture content is high. These soils are composed of fine-grained particles of clay minerals. Clay particles are capable of holding a film of adsorbed water on their surfaces. Adsorbed water is held by physiochemical forces and has properties substantially different from ordinary or chemically combined water. The attraction exerted by clay particles for water molecules gives these materials plasticity. Plasticity is a property of the fine-grained portion of a soil that allows it to be deformed beyond the point of recovery without cracking or appreciable volume change. This property permits clay to be rolled into thin threads at some moisture contents without crumbling. Only clay minerals possess this property; thus, the degree of plasticity is a general index to the clay content of a soil. The terms “fat” and “lean” are sometimes used to distinguish between highly plastic and moderately plastic soils.

A.1.6.1. Soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture content changes. The boundaries between the different states as described by the moisture content at the time of changes are called “consistency” or “Atterberg limits.”

A.1.6.2. The liquid limit (LL) is the moisture content at an arbitrary limit between the liquid and plastic states of a soil. Above this value, the soil is presumed to be a liquid and flows freely under its own weight. Below this value, it will deform under pressure without crumbling, provided the soil exhibits a plastic state.

A.1.6.3. The plastic limit (PL) is the moisture content at an arbitrary limit between the plastic and brittle states. As the sample is dried, the semisolid state is reached when the soil is no longer pliable and crumbles under pressure.

A.1.6.4. Between the liquid and plastic limits is the plastic range. The numerical difference in moisture contents between the two limits is called the plasticity index (PI). It defines the range of moisture content of the soil in a plastic state.

(PI = LL - PL)

A.1.7. Organic Soils. Soils having a high content of organic material are described as organic soils. They usually are very compressible and have poor load-maintaining properties.

Table A-2. Soil Characteristics Pertinent to Roads and Airfields – Part 1

Soil Type		Letter Symbol		Value as Subbase or Subgrade	Value as Base Course	Potential Frost Action	Compressibility And Expansion
Coarse Grained Soils	Gravel and Gravelly Soils	GW		Excellent	Good	None to Very Slight	Almost None
		GP		Good to Excellent	Poor to Fair	None to Very Slight	Almost None
		GM	d	Good to Excellent	Fair to Good	Slight to Medium	Very Slight
			u	Good	Poor	Slight to Medium	Slight
		GC		Fair to Good	Poor	Slight to Medium	Slight
	Sands and Sandy Soils	SW		Good	Poor	None to Very Slight	Almost None
		SP		Fair to Good	Poor to Not Suitable	None to Very Slight	Almost None
		SM	d	Good	Poor	Slight to High	Very Slight
			u	Fair to Good	Not Suitable	Slight to High	Slight to Medium
		SC		Fair to Good	Not Suitable	Slight to High	Slight to Medium
Fine Grained Soils	Silts and Clays LL < 50	ML		Fair to Poor	Not Suitable	Medium to Very High	Slight to Medium
		CL		Fair to Poor	Not Suitable	Medium to High	Medium
		OL		Poor	Not Suitable	Medium to High	Medium to High
	Silts and Clays LL > 50	MH		Poor	Not Suitable	Medium to Very High	High
		CH		Poor to Very Poor	Not Suitable	Medium	High
		OH		Poor to Very Poor	Not Suitable	Medium	High
Highly Organic Soils		Pt		Not Suitable	Not Suitable	Slight	Very High

Notes: Division of GM and SM groups into subdivisions of d and u are for roads and airfields.
Suffix d is used when the liquid limit is 28 or less and the plasticity index is 6 or more.
Suffix u is used when the liquid limit is greater than 28.

Table A-3. Soil Characteristics Pertinent to Roads and Airfields – Part 2

Soil Type		Letter Symbol		Drainage Characteristics	Unit Dry Weight (lb/ft^3)	Field CBR	Subgrade Modulus (lb/ft^3)
Coarse Grained Soils	Gravel and Gravelly Soils	GW		Excellent	125 – 140	60 - 80	300 or More
		GP		Excellent	110 – 130	25 - 60	300 or More
		GM	d	Fair to Poor	130 – 145	40 - 80	300 or More
			u	Poor to Impervious	120 - 140	20 - 40	200 to 300
		GC		Poor to Impervious	120 - 140	20 - 40	200 to 300
	Sands and Sandy Soils	SW		Excellent	110 – 130	20 - 40	200 to 300
		SP		Excellent	100 – 120	10 - 25	200 to 300
		SM	d	Fair to Poor	120 - 135	20 - 40	200 to 300
			u	Poor to Impervious	105 - 130	10 - 20	200 to 300
		SC		Poor to Impervious	105 - 130	10 - 20	200 to 300
Fine Grained Soils	Silts and Clays LL < 50	ML		Fair to Poor	100 - 125	5 - 15	100 to 200
		CL		Impervious	100 – 125	5 - 15	100 to 200
		OL		Poor	90 – 105	4 - 8	100 to 200
	Silts and Clays LL > 50	MH		Fair to Poor	80 – 100	4 - 8	100 to 200
		CH		Impervious	90 - 110	3 - 5	50 to 100
		OH		Impervious	80 - 105	3 - 5	50 to 100
Highly Organic Soils		Pt		Fair to Poor	--	--	--

Notes: Division of GM and SM groups into subdivisions of d and u are for roads and airfields.
Suffix d is used when the liquid limit is 28 or less and the plasticity index is 6 or more.
Suffix u is used when the liquid limit is greater than 28.

A.2. Soil Classification. Soils seldom exist separately as sand, gravel, or any other single component in nature. They are usually mixtures with varying proportions of different sized particles. Each component contributes to the characteristics of the mixture. The USCS is based on the characteristics that indicate how a soil will behave as a construction material. The physical properties determined by appropriate tests and calculations are used to classify the soil. The criteria for identifying the different soil types are described in Table A-4 and the following paragraphs.

A.2.1. Categories. In the USCS, all soils are divided into three major categories: coarse grained, fine grained, and peat. The first two are differentiated by grain size, whereas the third is identified by the presence of large amounts of organic material.

A.2.2. Groups. Each of the major categories is subdivided into groups and a letter symbol is assigned to each group.

Soil Groups	Symbol
Gravel	G
Sand	S
Silt	M
Clay	C

Soil Characteristics	Symbol
Well-graded	W
Poorly-graded	P
High compressibility	H
Low compressibility	L
Organic (peat)	Pt
Organic (silts and clays)	O
Liquid limits less than 50	L
Liquid limits over 50	H

Table A-4. USCS

Major Divisions			Symbol	Field Identification Procedures		
Coarse-Grained Soils (More than half of the material is larger than No. 200 sieve)	Gravels (More than half of coarse fraction is larger than No. 4 sieve)	Gravels < 5% Fines	GW	Wide range in grain sizes, all intermediate sizes substantially represented		
			GP	Predominantly one size or some intermediate sizes missing		
		Gravels > 12% Fines	GM	Nonplastic fines or fines with little plasticity (see ML below)		
			GC	Plastic fines (see CL below)		
	Sands (More than half of coarse fraction is smaller than No. 4 sieve)	Sands < 5% Fines	SW	Wide range in grain sizes, all intermediate sizes substantially represented		
			SP	Predominantly one size or some intermediate sizes missing		
		Sands > 12% Fines	SM	Nonplastic fines or fines with little plasticity (see ML below)		
			SC	Plastic fines (see CL below)		
Fine-Grained Soils (More than half of the material is smaller than No. 200 sieve)				Identification Procedure On Fraction Smaller than No. 40 Sieve		
				Dry Strength	Wet Shake	Thread or Ribbon
	Silts and Clays LL < 50		ML	None to Slight	Quick to Slow	None
			CL	Medium to High	None to Very Slow	Medium
			OL	Slight to Medium	Slow	Slight
	Silts and Clays LL > 50		MH	Slight to Medium	Slow to None	Slight to Medium
			CH	High to Very High	None	High
			OH	Medium to High	None to Very Slow	Slight to Medium

Highly Organic Soils	Pt	Readily identified by color, odor, spongy feel, and frequently by fibrous texture

A.2.3. Coarse-Grained Soils. Coarse-grained soils are defined as those in which at least half the material by weight is larger than a No. 200 sieve. They are divided into two major divisions: gravels and sands. A coarse-grained soil is classified as gravel if more than half the coarse fraction by weight is larger than a No. 4 sieve. It is sand if more than half the coarse fraction by weight is smaller than a No. 4 sieve.

A.2.3.1. Coarse-Grained Soils with Less than 5 Percent Nonplastic Fines. The first letter of the symbol indicates a gravel or sand. The second letter is determined by the grain size distribution curve.

- **GW** Well-graded gravels or gravel-sand mixtures
- **GP** Poorly graded gravels or gravel-sand mixtures
- **SW** Well-graded sands or gravelly sands
- **SP** Poorly graded sands or gravelly sands

A.2.3.2. Coarse-Grained Soils Containing more than 12 Percent Fines. The first letter of the symbol indicates a gravel or sand. The second letter is based upon the plasticity characteristics of the portion of the material passing the No. 40 sieve. The symbol M usually designates a fine-grained soil of little or no plasticity. The symbol C is used to indicate that the binder soil is predominantly clayey in nature.

- **GM** Silty gravels or gravel-sand-silt mixtures. The Atterberg limits plot below the A-line on the plasticity chart or the plastic index is less than 4.
- **GC** Clayey gravels or gravel-sand-clay mixtures. The Atterberg limits plot above the A-line with a plastic index of more than 7.
- **SM** Silty sands or sand-silt mixtures. The Atterberg limits plot below the A-line, or the plastic index is less than 4.
- **SC** Clayey sands or sand-clay mixtures. The Atterberg limits plot above the A-line with a plastic index of more than 7.

A.2.3.3. Borderline Coarse-Grained Soils. Coarse-grained soils that contain between 5 and 12 percent of material passing the No. 200 sieve are classified as borderline and are given a dual symbol (for example, GW-GM). Select the two that are believed to be the most representative of the probable behavior of the soil. In cases of doubt, the symbol representing the poorer of the possible groupings should be used, depending upon the judgment of the engineer, from the standpoint of the climatic region.

A.2.4. Fine-Grained Soils. Fine-grained soils are those in which more than half the material by weight passes a No. 200 sieve. Fine-grained soils are not classified on the basis of grain-size distribution, but according to plasticity and compressibility.

A.2.4.1. Silts.

- **ML** Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity. The plastic index plots below the A-line and the liquid limit is less than 50.
- **MH** Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, plastic silts. The plastic index plots below the A-line and the liquid limit is more than 50.
- **OL** Organic silts and organic silt-clays of low plasticity. The plastic index plots below the A-line and the liquid limit is less than 50.

A.2.4.2. Clays.

- **CL** Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, and lean clays. The plastic index plots above the A-line and the liquid limit is less than 50.
- **CH** Inorganic clays of high plasticity (fat clays). The plastic index plots above the A-line and the liquid limit is more than 50.
- **OH** Organic clays of medium to high plasticity. The plastic index plots below the A-line and the liquid limit is more than 50.

A.2.4.3. Borderline Fine-Grained Soils. Fine-grained soils that plot in the shaded portion of the plasticity chart are borderline cases and should be given dual symbols (for example, CL-ML).

A.2.5. Highly Organic Soils. A special classification (Pt) is reserved for the highly organic soils, such as peat, which have many characteristics undesirable for use as foundations and construction materials. No laboratory criteria are established for these soils, as they can be identified in the field by their distinctive color, odor, spongy feel, and fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

A.3. Field Identification of Soil. Lack of time and facilities often make laboratory testing impossible in contingency evaluations. Even where laboratory tests are to follow, field identification tests can reduce the number of laboratory test samples required. In expedient evaluations where the DCP is the primary instrument used to determine soil strength, proper identification of soil type is required to determine the correct correlation factor to be used in computing CBRs. The correlations for CL and CH soils vary significantly from other materials (see Tables 2 and 3 and Figure 6). Experience is the greatest asset in field identification and this is gained by getting the feel of soils during laboratory testing. If expedient field tests to identify clay soils are inconclusive, testing should be conducted using laboratory Atterberg limits equipment and procedures.

A.3.1. Equipment Required. Field tests may be performed with little or no equipment other than a small amount of water; however, accuracy and uniformity of results will be increased by the proper use of available equipment. The following is a suggested list:

- Sieves:
  - No. 40. **All tests used to identify the fine-grained portions of any soil are performed on the portion of the material that passes the No. 40 sieve.** If this sieve is not available, spreading the material on a flat surface and removing the gravel and larger sand particles may make a rough separation.
  - No. 4. This sieve defines the limit between gravels and sands.
  - No. 200. This sieve defines the limit between sands and fines. The sedimentation test may also be used to separate the sands and fines. This test requires a transparent cup or jar.
- Pan and oven or other heating device.
- Mixing bowl and pestle.
- Scales or balances.
- Knife or small spatula.

Figure A-1. Field Identification Equipment

A.3.2. Tests for Field Identification. The USCS considers three soil properties: the percentage of gravel, sand, or fines; the shape of the grain-size distribution curve; and the plasticity. The purpose of field tests is to get the best possible identification and classification in the field. Tests appropriate to a given soil sample should be made. When a simple visual examination will define the soil type, only the tests needed to verify this are necessary. When results from a test are inconclusive, some of the similar tests should be tried to establish the best identification.

A.3.2.1. Visual Examination. This test should establish the color, grain sizes, grain shapes of the coarse-grained portion, approximate gradation, and some properties of the undisturbed soil.

A.3.2.1.1. Color. Color helps in distinguishing between soil types and aids in identifying soil types. It may also indicate the presence of certain chemicals, minerals, or impurities. Color often varies with moisture content. Thus the moisture content at the time of identification should be included. Colors generally become darker as the moisture content increases and lighter as the soil dries. Some fine-grained soil (OH, OL) with dark, drab shades of brown or gray, including almost black, contain organic material. In contrast, clean, bright shades of gray, olive green, brown, red, yellow, and white are associated with inorganic soils. Gray-blue or gray-and-yellow mottled colors frequently result from poor drainage. Red, yellow, and yellowish-brown result from the presence of iron oxides. White to pink may indicate considerable silica, calcium carbonate, or aluminum compounds.

A.3.2.1.2. Grain Size. The maximum particle size of each sample should be established to determine the upper limit of the gradation curve. Gravels range down to the size of peas; sands start just below this size and decrease until the individual grains are just distinguishable by the naked eye. **Silt and clay particles are indistinguishable as individual particles.**

A.3.2.1.3. Grain Shape. The shapes of the visible particles should be determined. They may vary from sharp and angular to smooth and rounded.

A.3.2.1.4. Grain Size Distribution. Examining a dry sample spread on a flat surface can make an approximate identification. All lumps should be pulverized until individual grains are exposed, but not broken. A rubber-faced or wooden pestle and a mixing bowl are recommended, but mashing the sample underfoot on a smooth surface will suffice for an approximate identification. Separate the larger grains (gravels and some sands) by picking them out individually. Examine the remainder of the soil and estimate the proportions of visible individual particles and fines. Convert these estimates into percentages by weight of the total sample. If the fines exceed 50 percent, the soil is considered fine-grained (M, C, or O). If the coarse material exceeds 50 percent, the soil is coarse-grained (G or S). Examine coarse-grained soil for gradation of the particle sizes from the largest to the smallest. A good distribution of all sizes means the soil is well-graded (W). Overabundance or lack of any size means the material is poorly graded (P). Estimate the percentage of the fine-grained portion of the coarse-grained soil for further classification. Fine-grained soils and fine-grained portions of coarse-grained soils require other tests for identification.

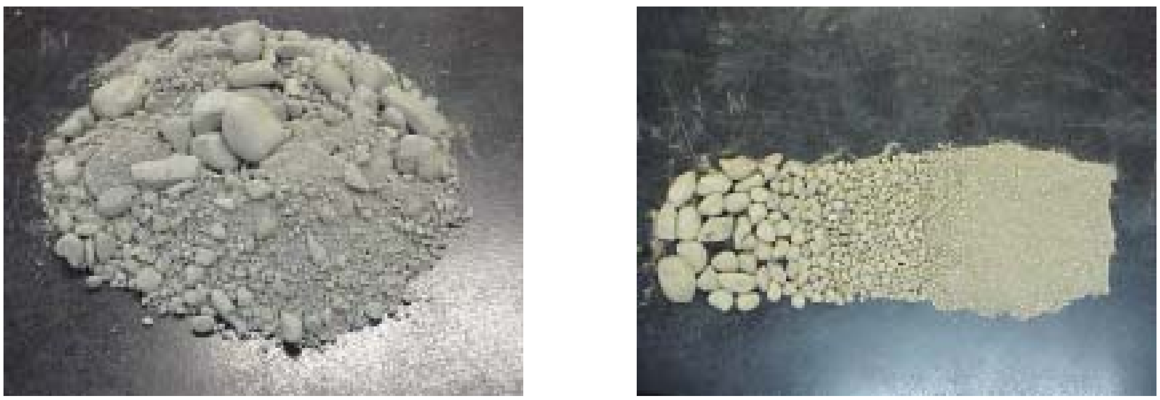


Figure A-2. Grain Size Distribution

A.3.2.1.5. Undisturbed Soil Properties. Characteristics of the soil in the undisturbed state may be helpful in identification. The compactness of gravels or sands may be loose, medium, or dense. Clays may be hard, stiff, or soft. The ease or difficulty of sample removal should be recorded. The moisture content of the soil influences the in-place characteristics. It is helpful to know the weather just prior to and during the field evaluation to determine how the soil has reacted or will react to weather changes. The presence of decayed roots, leaves, grasses, and other vegetable matter in organic soils produces soil which is usually dark when moist, having a soft spongy feel and a distinctive odor of rotting organic matter. The odor may be musky and slightly offensive. The odor is especially apparent in undisturbed conditions or in fresh samples. It is less pronounced as the sample is exposed to air. The odor can be made stronger by heating a wet sample.

A.3.2.2. Sedimentation Test. From visual examination it is relatively easy to approximate the proportions of gravels and sands in a soil sample. Determining the proportion of fine-grained particles is more difficult but just as important. In the laboratory and in some field testing situations, the fines may be separated from the sample using the No. 200 sieve. The sedimentation test provides an alternate field method to separate fines from the sand particles in a soil sample.

Larger particles settle more quickly than fines

Figure A-3. Sedimentation Test

Smaller particles will settle through water at a slower rate than large particles. Placing a small amount of the fine fraction of a soil (such as a heaping teaspoon) in a transparent cup or jar, covering it with about 5 inches of water, and agitating it by stirring or shaking will completely suspend the soil in water. With cohesive soils, it will be necessary to break up all lumps of soil before adding the water. After the soil particles have been dispersed in the water and then left, they will start to settle to the bottom, beginning with the larger sized particles, in time periods indicated in Table A-5.

Table A-5. Sedimentation Test

Approximate Time of Settlement in 5 Inches of Water	Grain Diameter	Differentiates
2 seconds	0.4 mm	Coarse sand - fine sand
30 seconds	0.072 mm (No. 200 sieve)	Sand - fines
10 minutes	0.03 mm	Coarse silt - fine silt
1 hour	0.01 mm	Silt - clay

Since all of the particles of soil larger than the No. 200 sieve will have settled to the bottom of the cup or jar 30 seconds after the mixture has been agitated, it follows that the particles still remaining in suspension are fines. The water containing the suspended fines should be carefully poured into another container 30 seconds after agitation, more water added to the cup or jar containing the coarse fraction, and the procedure repeated until the water-soil mixture becomes clear 30 seconds after mixing. The cup or jar will contain the coarse fraction of the soil and the other container will hold the fines. The water is then wicked or evaporated off and the relative amounts of fines and sands determined fairly accurately. In clay soils the clay particles will often form small lumps (flocculate) that will not break up in water. If after several repetitions of the test substantial amounts of clay are still present in the coarse material, the sand will feel slippery. Further mixing and grinding with a stick will be necessary to help break up these lumps.

A.3.2.3. Plasticity Tests. Fine-grained soil particles (those passing the No. 200 sieve) are generally not classified using gradation criteria but are identified primarily by characteristics related to plasticity. In the laboratory Atterberg tests are used to define the liquid and plastic limits of the soil and classify it. Expedient field tests have been developed to determine the cohesive and plastic characteristics of soil. **These field tests are performed only on material passing the No. 40 sieve**, the same fraction used in the laboratory tests.

A.3.2.3.1. Breaking or Dry Strength Test.

A.3.2.3.1.1. Pat Test.

A.3.2.3.1.1.1. Procedure: Prepare a pat of soil about 2 inches in diameter and 0.5 inch thick by molding it in a wet, plastic state. Allow the pat to dry completely (in the sun, in an oven, or inside the engine compartment), then grasp the pat between the thumbs and forefingers of both hands and attempt to break it. If the pat breaks, try to powder it by rubbing it between the thumb and forefinger of one hand.

A.3.2.3.1.1.2. Results:

- Pat cannot be broken nor powdered by finger pressure - Very highly plastic soil (CH).
- Pat can be broken with great effort, but cannot be powdered - Highly plastic soil (CL).
- Pat can be broken and powdered, but with some effort - Medium plastic soil (CL).
- Pat breaks easily and powders readily - Slightly plastic soil (ML, MH, or CL).
- Pat has little or no dry strength and crumbles or powders when picked up - Nonplastic soil (ML or MH) or (OL or OH).

Figure A-4. Dry Strength Pat Test

Note: Dry pats of highly plastic clays often display shrinkage cracks. Breaking the pat along such a crack may not give a true indication of the strength. It is important to distinguish between a break along such a crack and a clean, fresh break that indicates the true dry strength of the soil.

A.3.2.3.1.2. Ball Test (Alternative to Pat Test).

A.3.2.3.1.2.1. Procedure: Select enough material to mold into a ball about 1 inch in diameter. Mold the material until it has the consistency of putty, adding water as necessary. From the molded material, make at least three 0.5-inch-diameter balls as test specimens. Allow the test specimens to dry in the air, sun or by artificial means, as long as the temperature does not exceed 60 °C (140 °F), then test the strength of the material by crushing it between the fingers.

A.3.2.3.1.2.2. Results:

- No strength. The dry specimen crumbles into powder with mere finger pressure of handling. (ML)
- Low strength. The dry specimen crumbles into powder with some finger pressure. (ML or MH)
- Medium strength. The dry specimen breaks into pieces or crumbles with considerable finger pressure. (MH or CL)
- High strength. The dry specimen cannot be broken with finger pressure, but will break into pieces between the thumb and a hard surface. (CL or CH)
- Very high strength. The dry specimen cannot be broken between the thumb and a hard surface. (CH)

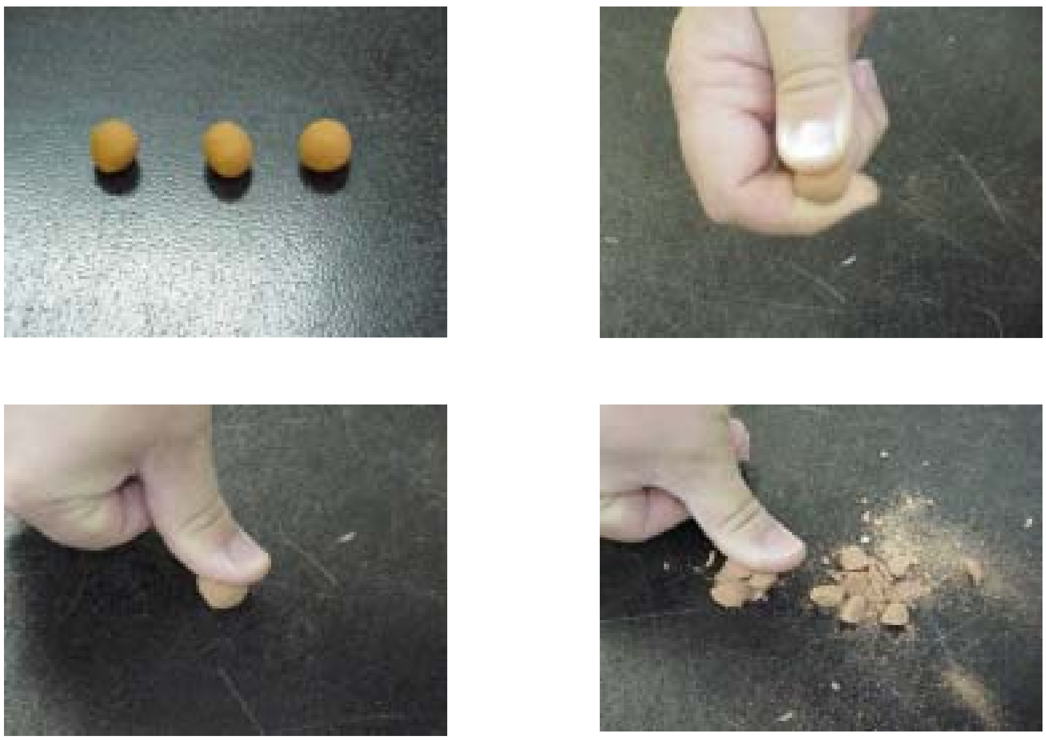


Figure A-5. Dry Strength Ball Test

Note: Natural dry lumps about 0.5 inch in diameter may be used, but do not use the results if any of the lumps contain particles of coarse sand. The presence of highly cementitious materials in the soil such as calcium carbonate may produce exceptionally high strengths.

A.3.2.3.2. Roll or Thread Test.

A.3.2.3.2.1. Procedure: A representative portion of the sample is mixed with water until it can be molded or shaped without sticking to the fingers. This moisture content is described as being just below the sticky limit. Prepare a nonabsorbent rolling surface by placing a sheet of glass or heavy wax paper on a flat or level support, then shape the sample into an elongated cylinder and rapidly roll the prepared soil cylinder on the surface into a thread approximately 0.125 inch in diameter. If the moist soil rolls into a thread, it has some plasticity. The number of times it can be rolled into a thread without crumbling is a measure of the degree of plasticity. Soils that cannot be rolled are nonplastic.

A.3.2.3.2.2. Results:

- Soil may be molded into a ball or cylinder and deformed under very firm finger pressure without crumbling or cracking - High plasticity (CH).
- Soil may be molded, but it cracks or crumbles under finger pressure - Medium plasticity (CL).
- Soil cannot be lumped into a ball or cylinder without breaking up - Low plasticity (CL, ML, or MH).
- Soil forms a soft, spongy ball or thread when molded - Organic material (OL or OH).
- Soil cannot be rolled into a thread at any moisture content - Nonplastic soil (ML or MH).
- The higher the soil is on the plasticity chart, the stiffer the threads are as they dry out and the tougher the lumps are if the soil is remolded after rolling.

Roll soil to 0.125 diameter thread

Figure A-6. Roll or Thread Test

Note: Micaceous silts and sands can be rolled due to the flaky nature of the mica. The wet shaking test is the only way to distinguish this property.

A.3.2.3.3. Ribbon Test.

A.3.2.3.3.1. Procedure: Prepare a soil sample as in the roll or thread test. Form a roll of soil about 0.5 to 0.75 inch in diameter and 3 to 5 inches long. Lay the roll across the palm of one hand (palm up) and starting at one end, squeeze the roll between the thumb and forefinger over the edge of the hand to form a flat unbroken ribbon about 0.125 to 0.25 inch thick. Allow the ribbon as formed to hang free and unsupported. Continue squeezing and handling the roll carefully to form the maximum length of ribbon that can be supported only by the cohesive properties of the soil.

A.3.2.3.3.2. Results:

- Sample holds together for a length of 8 to 10 inches without breaking - Highly plastic and highly compressive (CH).
- Soil can be ribboned only with difficulty to 3- to 8-inch lengths - Low plasticity (CL).

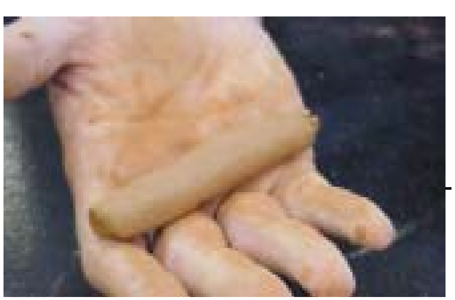


Figure A-7. Ribbon Test

A.3.2.3.4. Wet Shaking Test.

A.3.2.3.4.1. Procedure:

- Form a ball of soil about 0.75 inch in diameter, moistened with water to just below the sticky limit. Smooth the soil pat in the palm of the hand with a knife blade or small spatula, shake it horizontally, and strike the back of the hand vigorously against the other hand. When shaking, water comes to the surface of the sample producing a smooth, shiny, or livery appearance.
- Squeeze the sample between the thumb and forefinger of the other hand. The surface water will disappear. The surface will become dull and the sample will become firm, resisting deformation. Cracks will occur as pressure is continued and the sample will crumble.
- If the water content is still adequate, shaking the broken pieces will cause them to liquefy again and flow together.

A.3.2.3.4.2. Results: This process can only occur when the soil grains are bulky and noncohesive. Very fine sands and silts are readily identified by this test. Even small amounts of clay will tend to retard the reaction to this test.

- A rapid reaction is typical of nonplastic, fine sands and silts.
- A sluggish reaction indicates slight plasticity, indicating the silt has small amounts of clay or organic silts.
- No reaction at all does not indicate a complete absence of silt or fine sand.

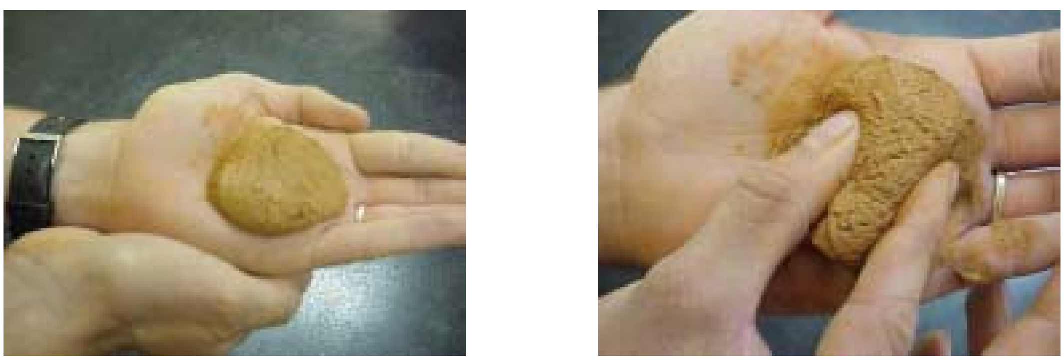


Figure A-8. Wet Shaking Test

A.3.2.3.5. Cast Test.

A.3.2.3.5.1. Procedure: Compress a handful of damp (not sticky) soil into a cylinder and observe its ability to be formed and handled.

A.3.2.3.5.2. Results:

- Soil crumbles when touched - GP, SP, SW, GW.
- Soil cast withstands careful handling - SM, SC.
- Soil cast can be handled freely - ML, MH.
- Soil cast withstands rough handling - CL, CH.

Figure A-9. Cast Test

A.3.2.3.6. Wash Test.

A.3.2.3.6.1. Procedure: Place a small dry sample of soil into the palm of the hand and cover with water. Note how quickly the water discolors and how long the fines are suspended. One variation is to look for mud puddles or create them, disturb the soil surface and note how the water discolors and how long the fines are suspended.

A.3.2.3.6.2. Results: If the water becomes completely discolored and hides the sand particles, there is evidence of greater than 5 percent silt content.

Note discoloration of water with fines

Figure A-10. Wash Test

A.3.2.3.7. Bite or Grit Test.

A.3.2.3.7.1. Procedure: Grind a small pinch of soil lightly between the teeth.

A.3.2.3.7.2. Results:

- Sandy soils. The sharp hard particles of even fine sands will grate very harshly between the teeth and will be highly objectionable.
- Silty soils. Silt grains are not particularly gritty, but their presence is still quite unpleasant and easily detected.
- Clayey soils. Clay grains feel smooth and powdery like flour. Dry lumps will stick when lightly touched with the tongue.

A.3.2.3.8. Shine Test.

A.3.2.3.8.1. Procedure: Rub a clay sample with a fingernail or smooth metal surface such as a knife blade.

A.3.2.3.8.2. Results:

- Highly plastic clay will produce a definite shine.
- Lean clays will remain dull.

A.3.2.3.9. Feel Test.

A.3.2.3.9.1. Consistency. Squeeze a piece of undisturbed soil between the thumb and forefinger. It may be hard, stiff, brittle, friable, sticky, plastic, or soft. Remold the soil by working it between the hands. This can indicate the natural water content. Clays which become fluid on remolding are probably near their liquid limit. If they remain stiff and crumble, they are probably below their liquid limit.

A.3.2.3.9.2. Texture. Rub a portion of fine-grained soil between the fingers or on a more sensitive area such as the inside of the wrist. Results are similar to the bite or grit test.

A.3.2.3.10. Use Table A-6 as a convenient way to track field identification tests. As tests are completed, mark the results on the chart. The results from the different tests may vary, but as the test results are plotted you will have a general indication of the soil type.

Table A-6. Summary of Field Identification Test Results

Field Identification of Soils						
Test	**Material**	**Soil Types**				
		ML	**MH**	**CL**	**CH**	**OL/OH**
Dry strength	< 40 sieve (wet)	No to low	Low to medium	Medium to high	Very high	Low
Roll/thread	< 40 sieve (sticky)	Low	Low to medium	Medium	High	Spongy
Ribbon	< 40 sieve (sticky)	No cohesion	Little cohesion	3 to 8 inches	8 to 10 inches	
Wet shake	< 40 sieve (sticky)	Slow to rapid	No to slow	No to slow	No	
Cast	Damp	Handle freely		Handle roughly		
Bite/feel	< 40 (< 200) sieve	Unpleasant		Smooth		
Shine		Dull			Shine	
Wash		Discolors quickly, > 5% silt				
Dust		> 10% silt				
Sedimentation		30 seconds		1 hour		

A.3.2.3.9. Steps for Field Identification of Soils.

A.3.2.3.9.1. Select representative sample of soil (approximately 1 pint).

A.3.2.3.9.2. Separate gravel size particles from remainder of soil (approximately 0.125 to 0.1875 inch and above).

- Gravel > 50 % = GW, GP, GM, GC
- Gravel < 50 % = SW, SP, SM, SC, or fine-grained ML, MH, CL, CH, OL, OH

A.3.2.3.9.3. Estimate percent fines (< 200 sieve) in original sample (sedimentation test may be helpful).

- For gravels:
  - If < 10% fines = GW or GP
  - If > 10% fines = GM or GC
- For sands:
  - If < 10% fines = SW or SP
  - If > 10% fines = SM or SC
- If > 50% of entire sample < 200 sieve = ML, MH, CL, CH, OL, OH

A.3.2.3.9.4. For gravels and sands with < 10% fines (GW, GP, SW, SP) check gradation to determine if well-graded or poorly graded.

- Wide range in grain sizes, with all intermediate sizes substantially represented = GW or SW
- Predominantly one size or some intermediate size missing (uniform or gap graded) = GP or SP

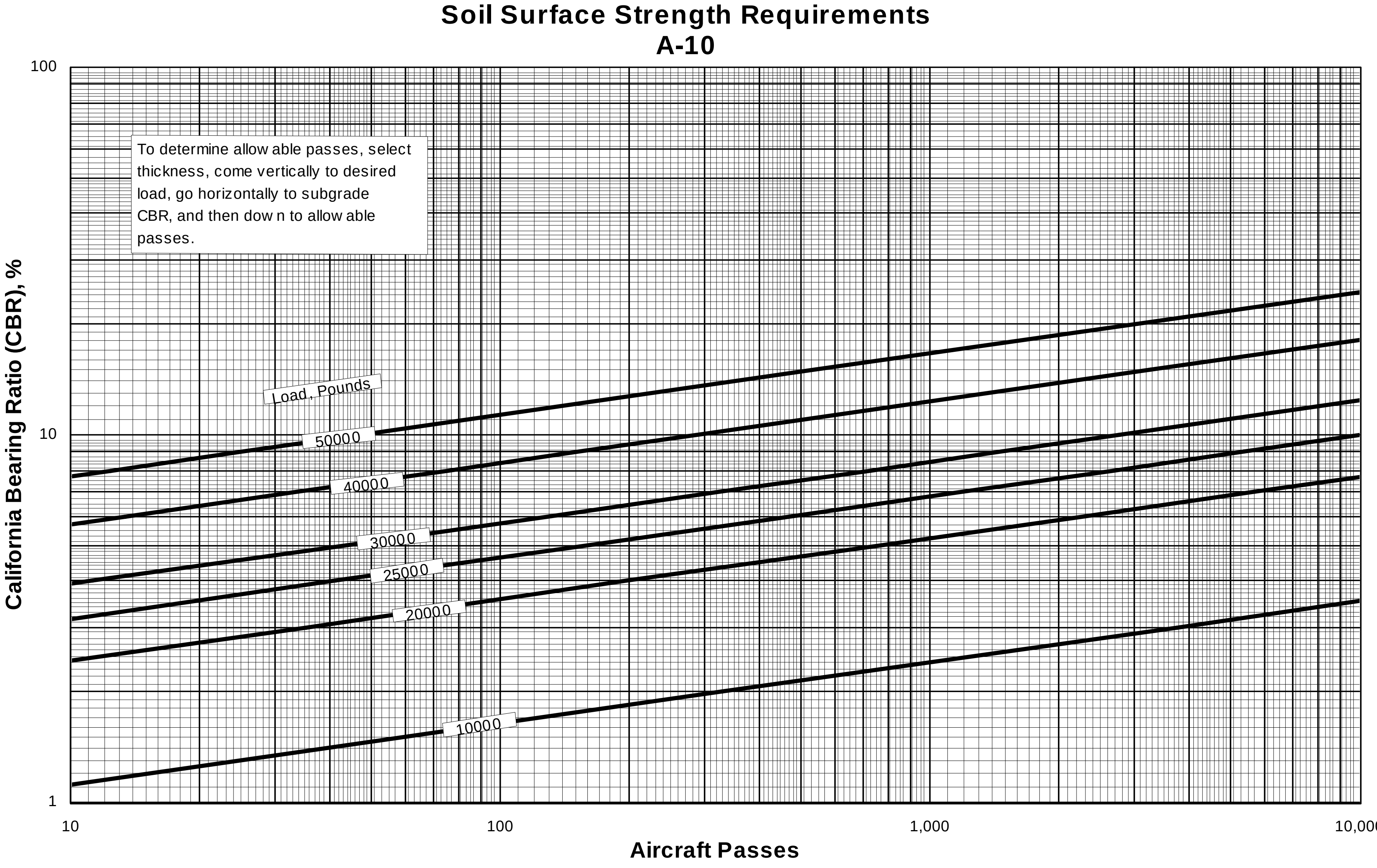
A.3.2.3.9.5. For fine-grained soils (ML, MH, CL, CH, OL, OH), test for organic matter:

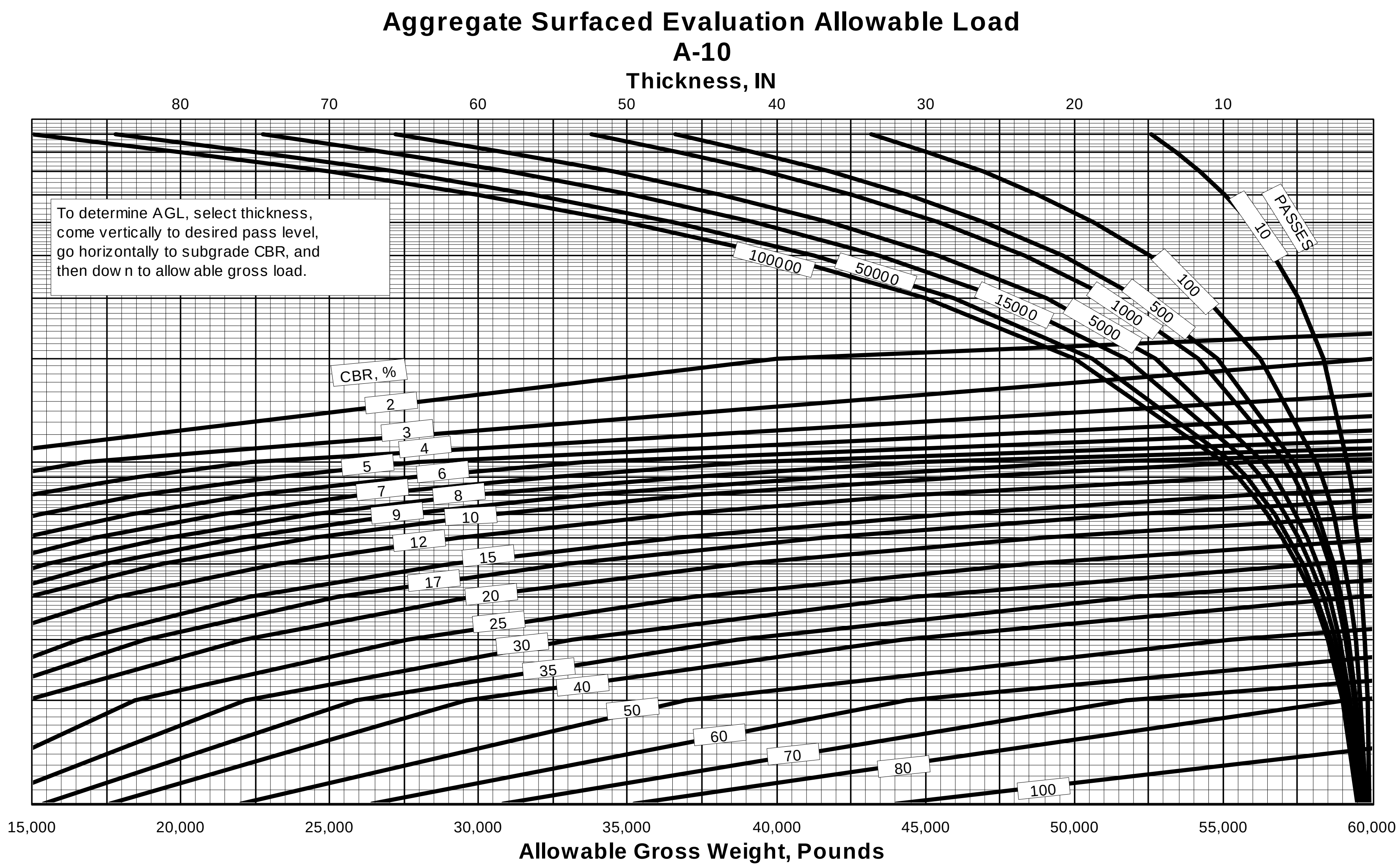
- If distinctive color, odor, spongy feel, or fibrous texture (particles of vegetation) = OL or OH
- If not, then = ML, MH, CL, CH

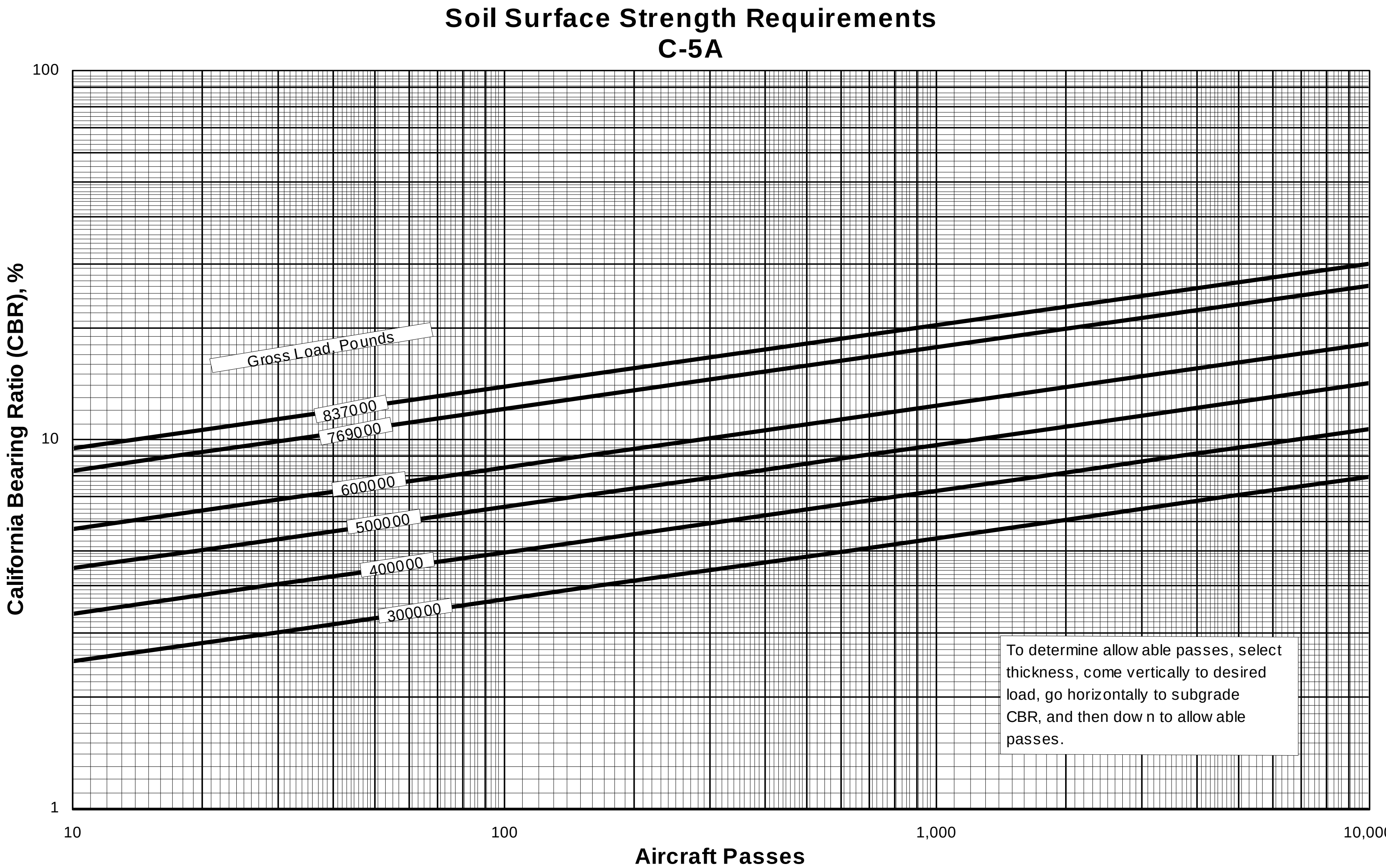
A.3.2.3.9.6. For fine-grained soils (ML, MH, CL, CH, OL, OH) and coarse-grained soils with > 10% fines (GM, GC, SM, SC):

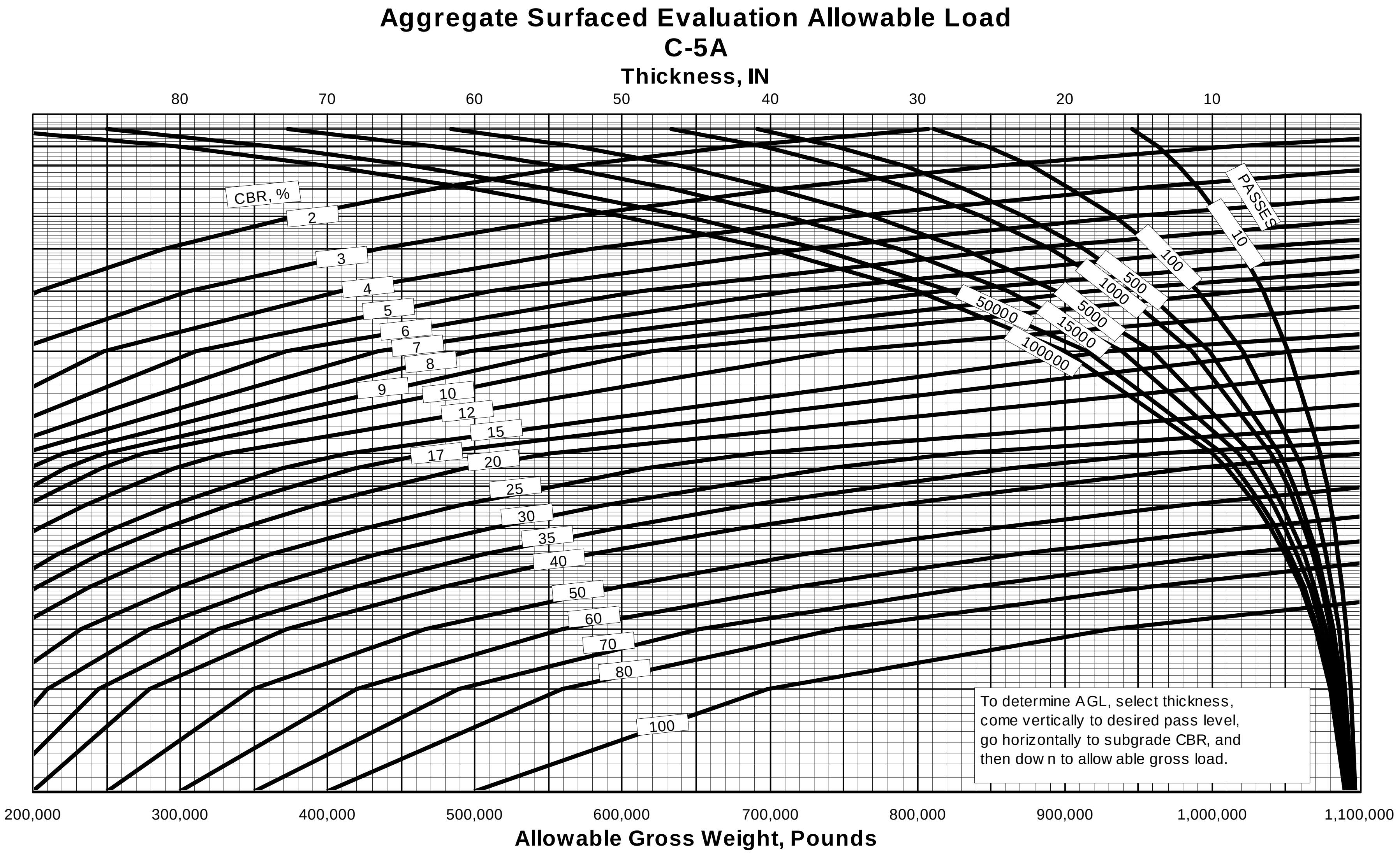
- Remove all material > 40 sieve.
- Perform field plasticity tests on portion < 40 sieve to determine cohesive and plastic characteristics.
- Plot results on Summary of Field Identification Test Results (Table A-6).
- Perform tests, as required, until results are conclusive.

Appendix B: Unsurfaced/Aggregate Surfaced Evaluation Curves

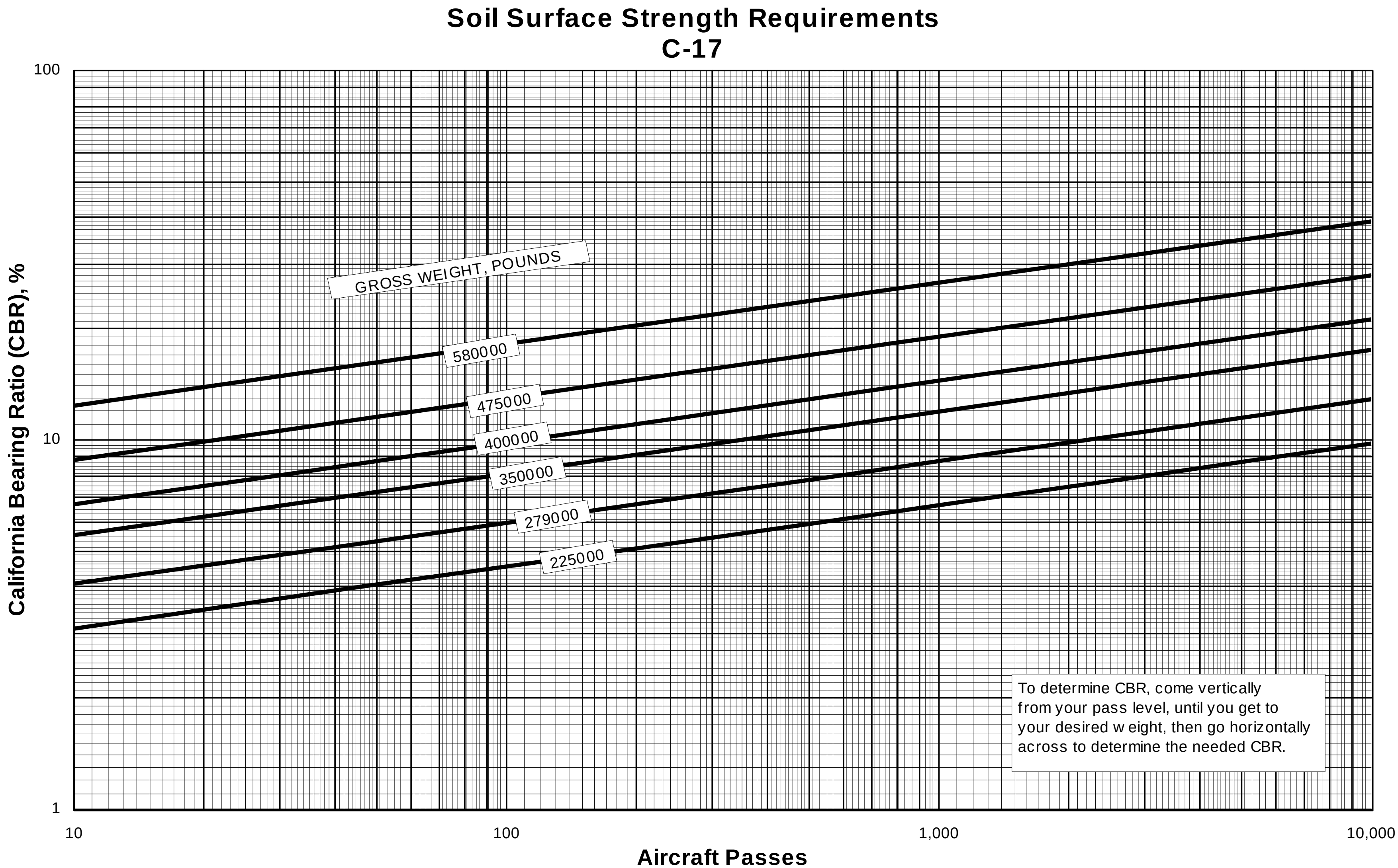



Aggregate Surfaced Evaluation Allowable Load
A-10
Thickness, IN
80
70
60
50
40
30
20
10
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then down to allowable gross load.
PASSES
10
100
500
1000
5000
15000
50000
100000
CBR, %
2
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
100
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
Allowable Gross Weight, Pounds

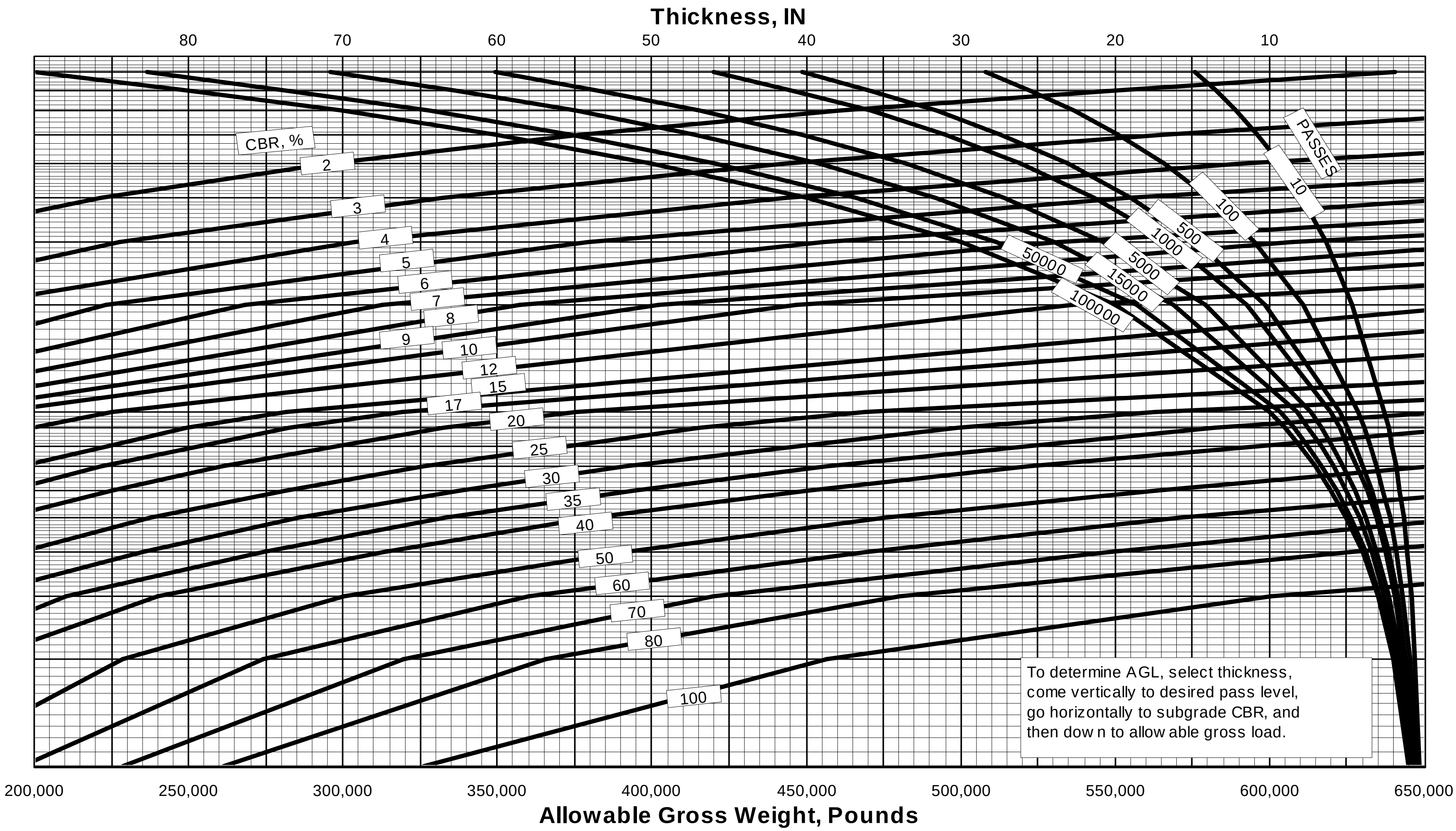

Soil Surface Strength Requirements
C-5A
California Bearing Ratio (CBR), %
Aircraft Passes
100
10
1
10
100
1,000
10,000
Gross Load, Pounds
837000
769000
600000
500000
400000
300000
To determine allow able passes, select thickness, come vertically to desired load, go horizontally to subgrade CBR, and then dow n to allow able passes.

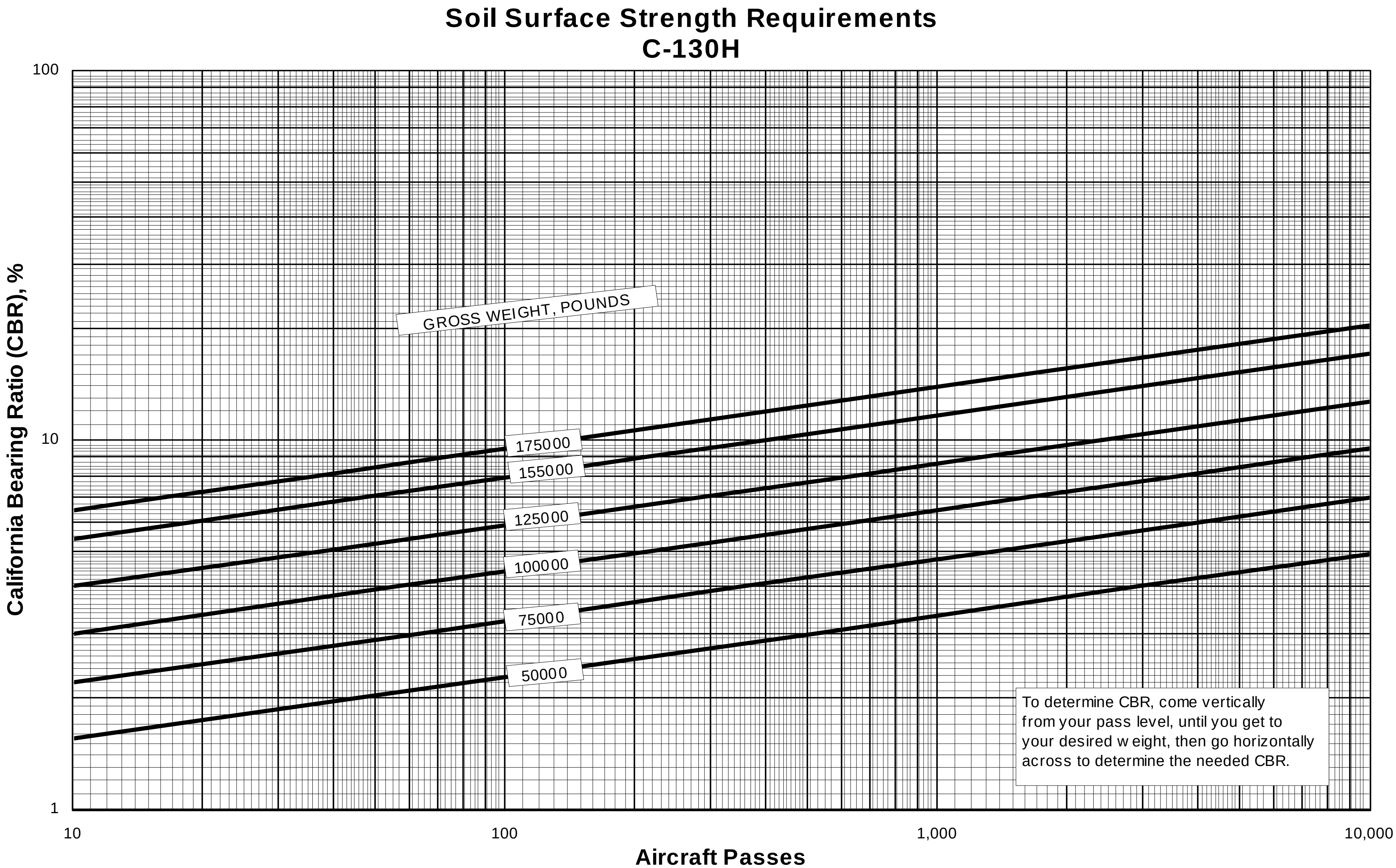


Aggregate Surfaced Evaluation Allowable Load
C-5A
Thickness, IN
80
70
60
50
40
30
20
10
CBR, %
2
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
100
PASSES
10
100
500
1000
5000
15000
50000
100000
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then down to allowable gross load.
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
Allowable Gross Weight, Pounds

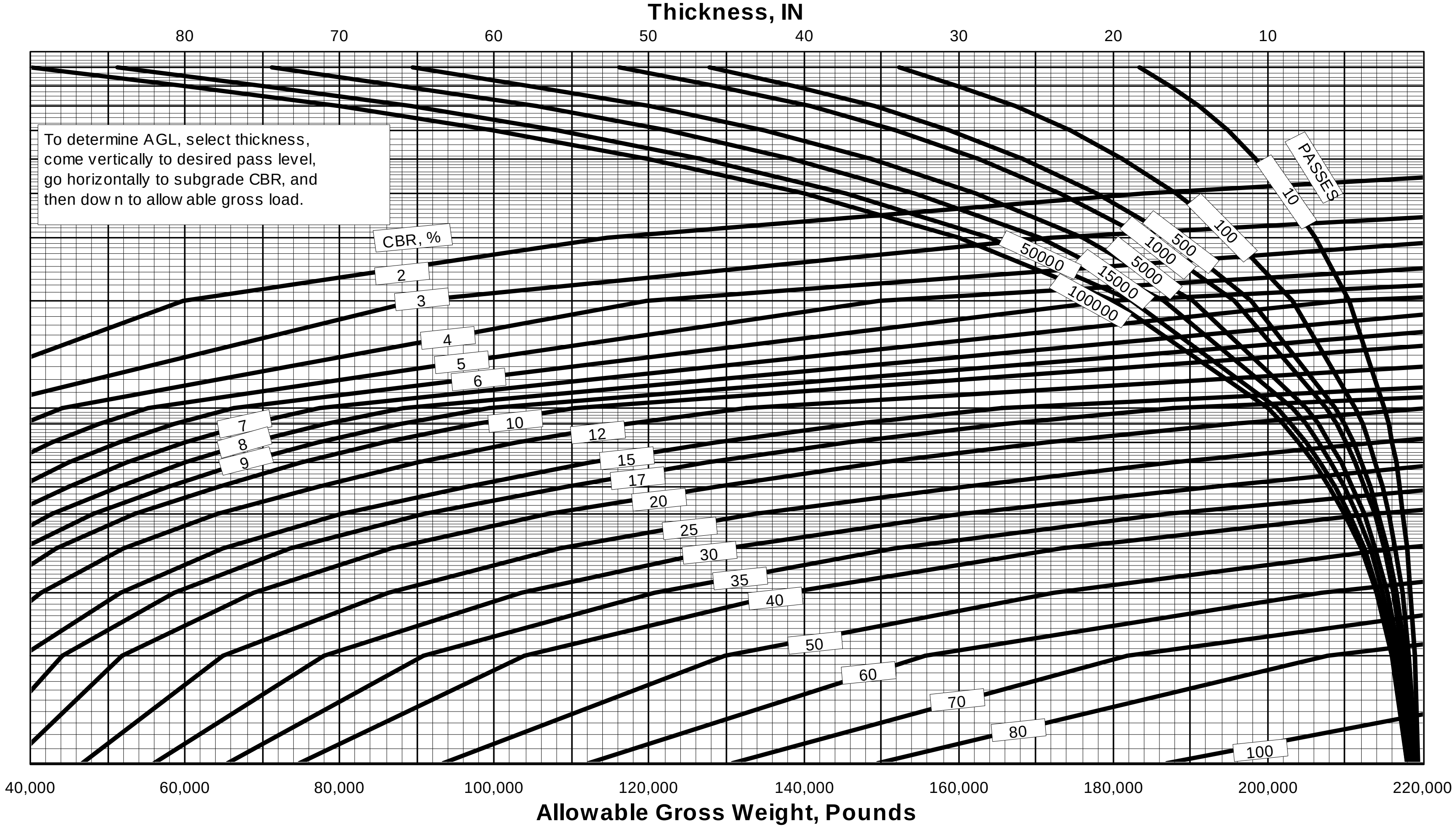

Soil Surface Strength Requirements
C-17
California Bearing Ratio (CBR), %
100
10
1
10
100
1,000
10,000
Aircraft Passes
GROSS WEIGHT, POUNDS
580000
475000
400000
350000
279000
225000
To determine CBR, come vertically from your pass level, until you get to your desired w eight, then go horizontally across to determine the needed CBR.

Aggregate Surfaced Evaluation Allowable Load
C-17

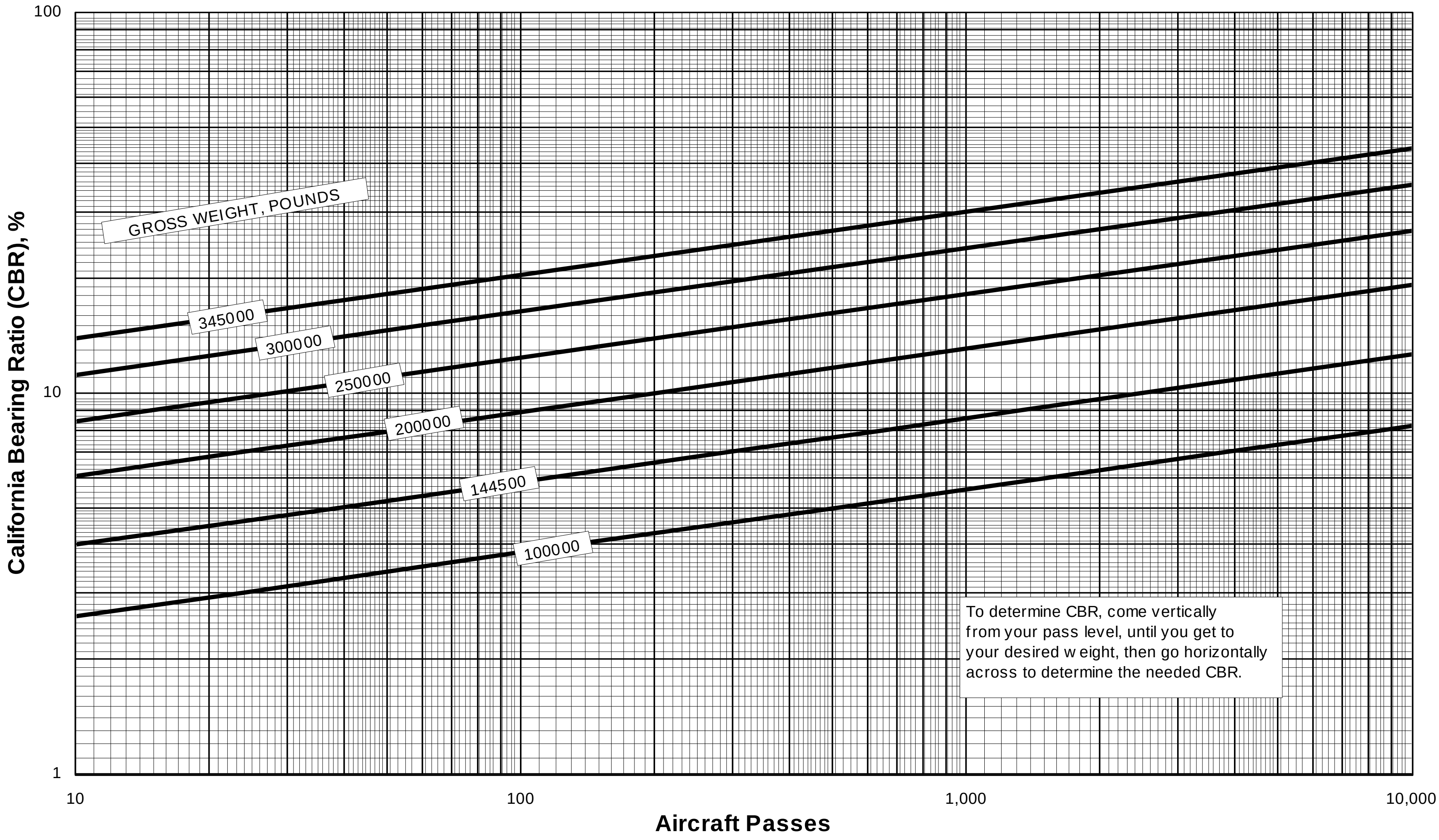



Soil Surface Strength Requirements
C-130H
100
10
1
California Bearing Ratio (CBR), %
GROSS WEIGHT, POUNDS
175000
155000
125000
100000
75000
50000
To determine CBR, come vertically from your pass level, until you get to your desired w eight, then go horizontally across to determine the needed CBR.
10
100
1,000
10,000
Aircraft Passes

Aggregate Surfaced Evaluation Allowable Load
C-130H

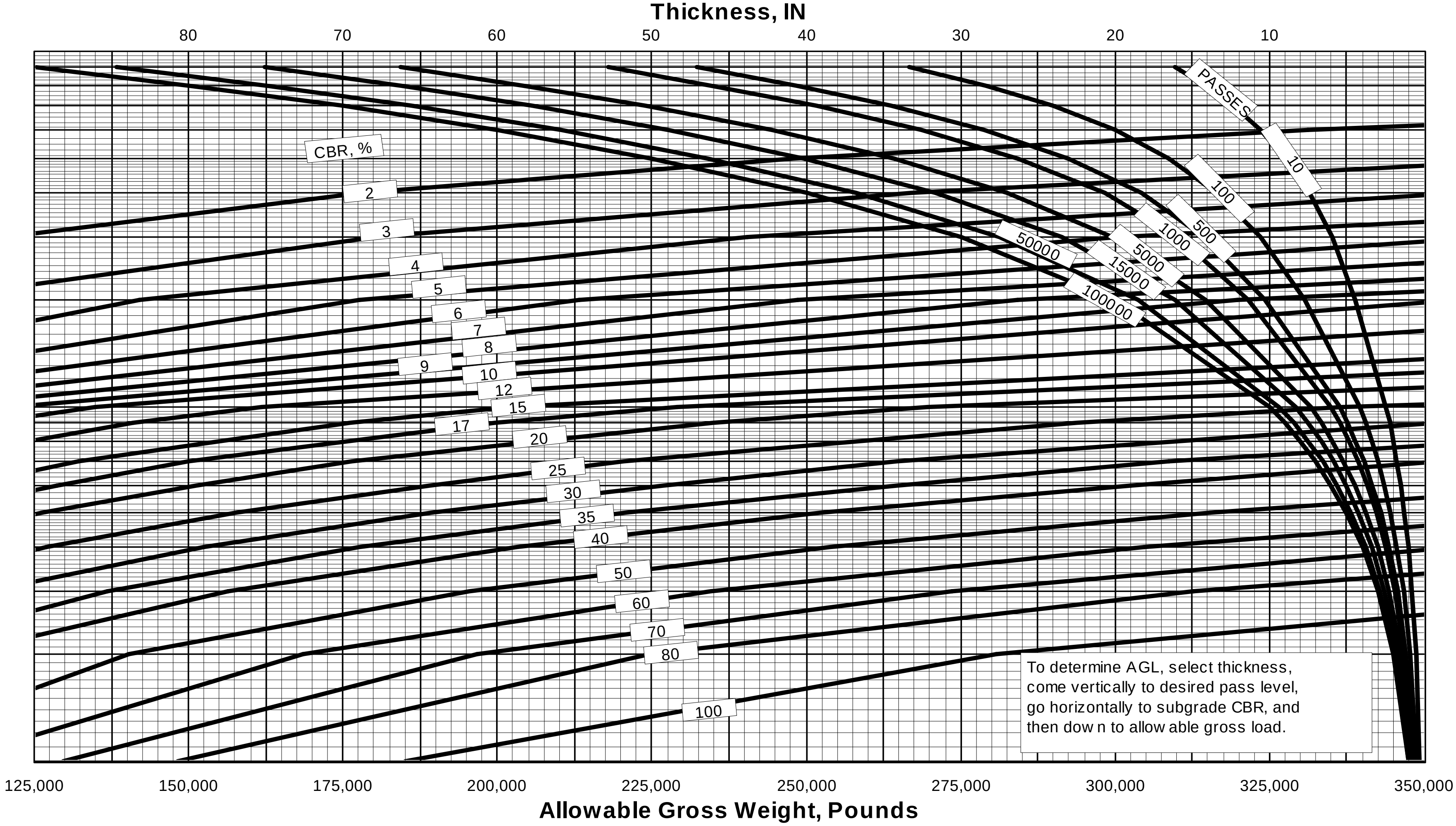


Soil Surface Strength Requirements
C-141

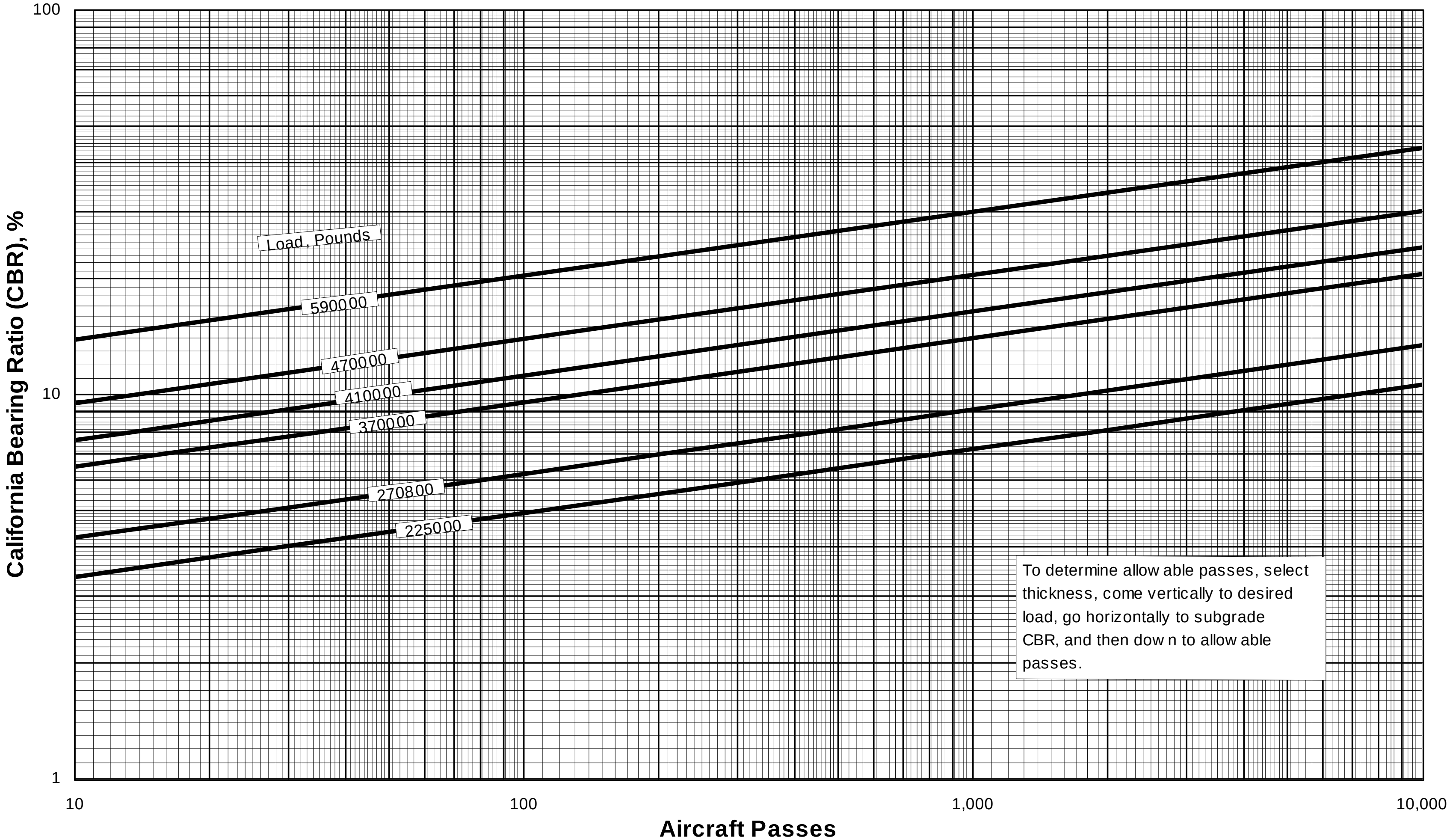


Aggregate Surfaced Evaluation Allowable Load

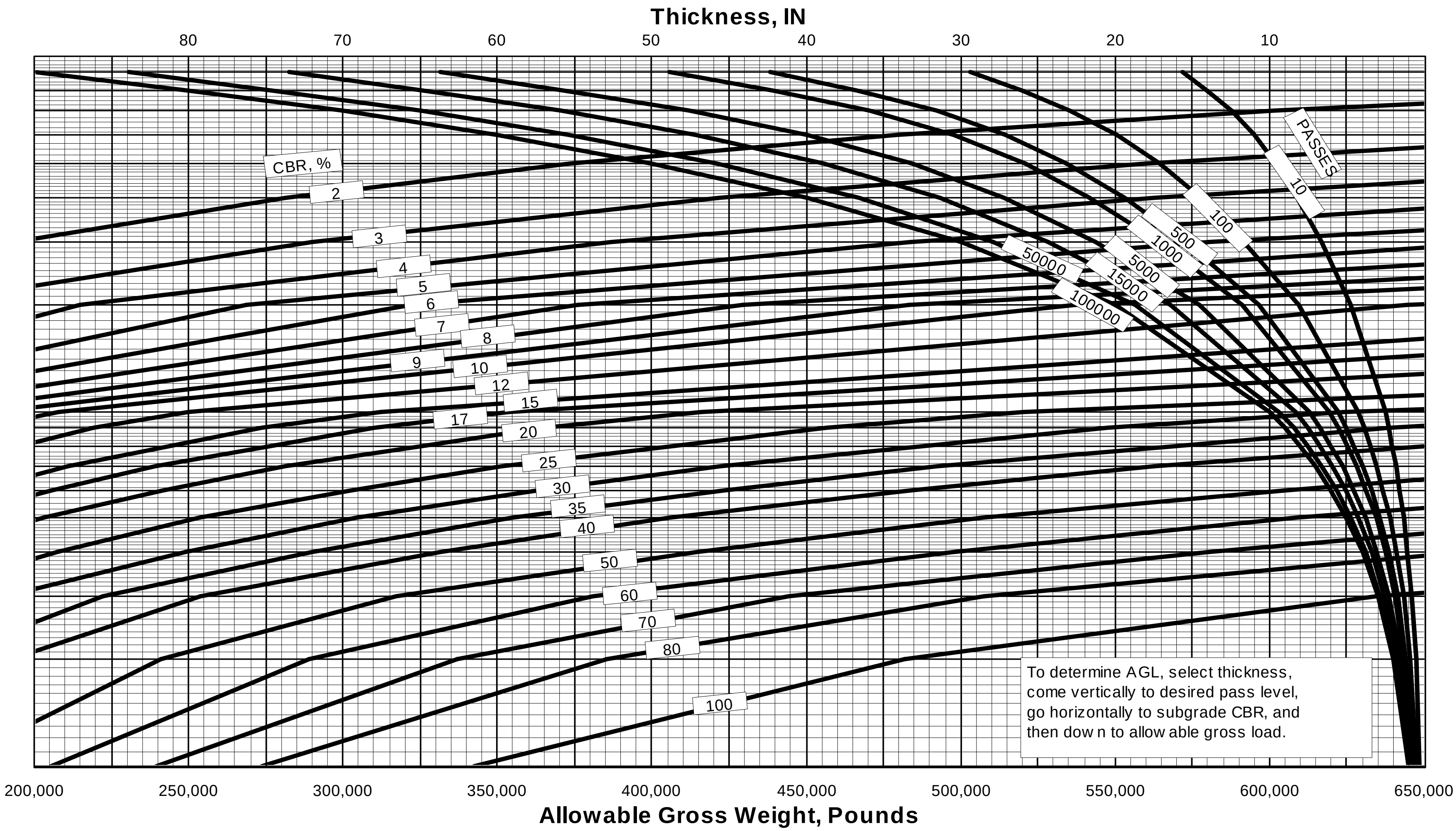
C-141

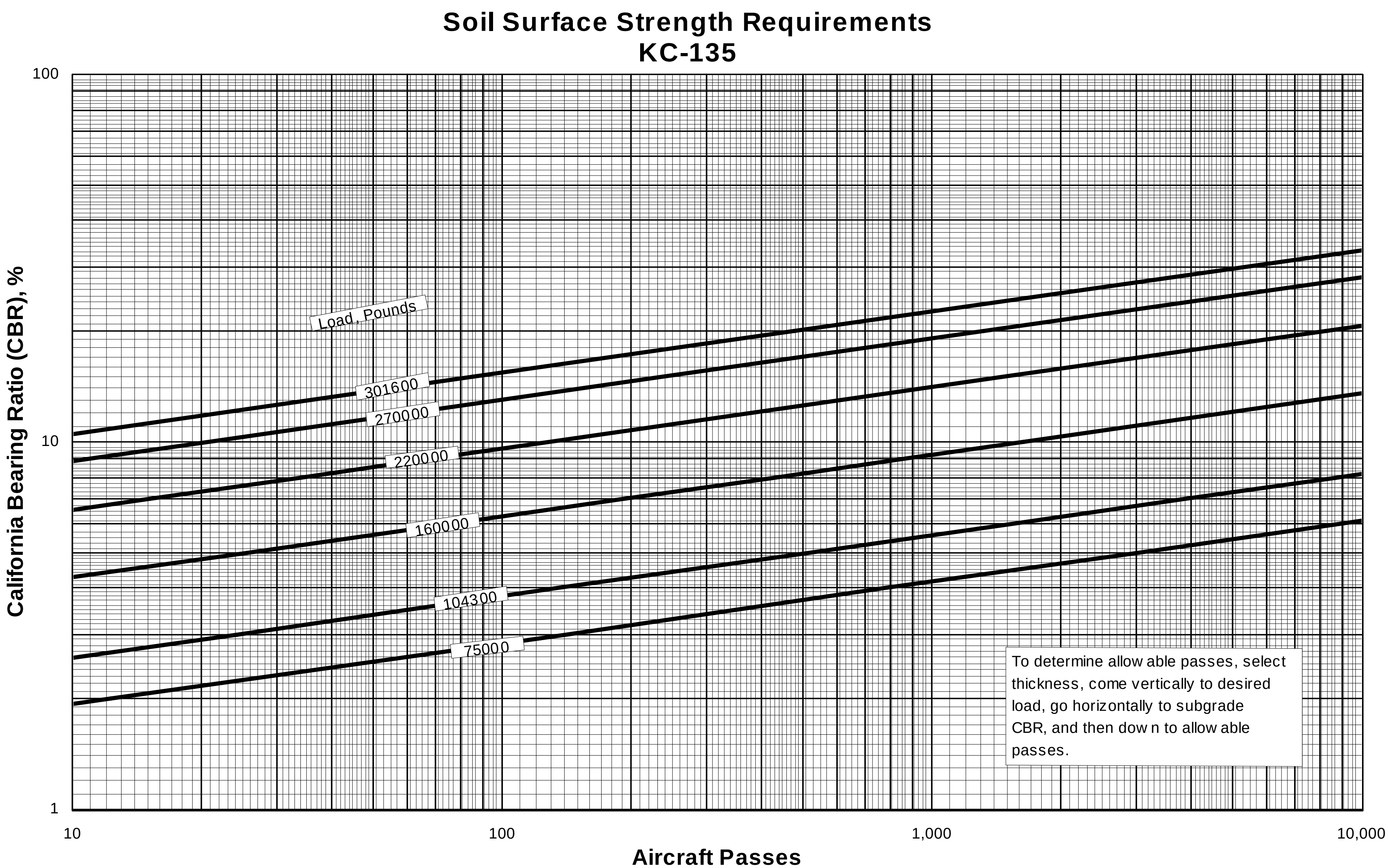


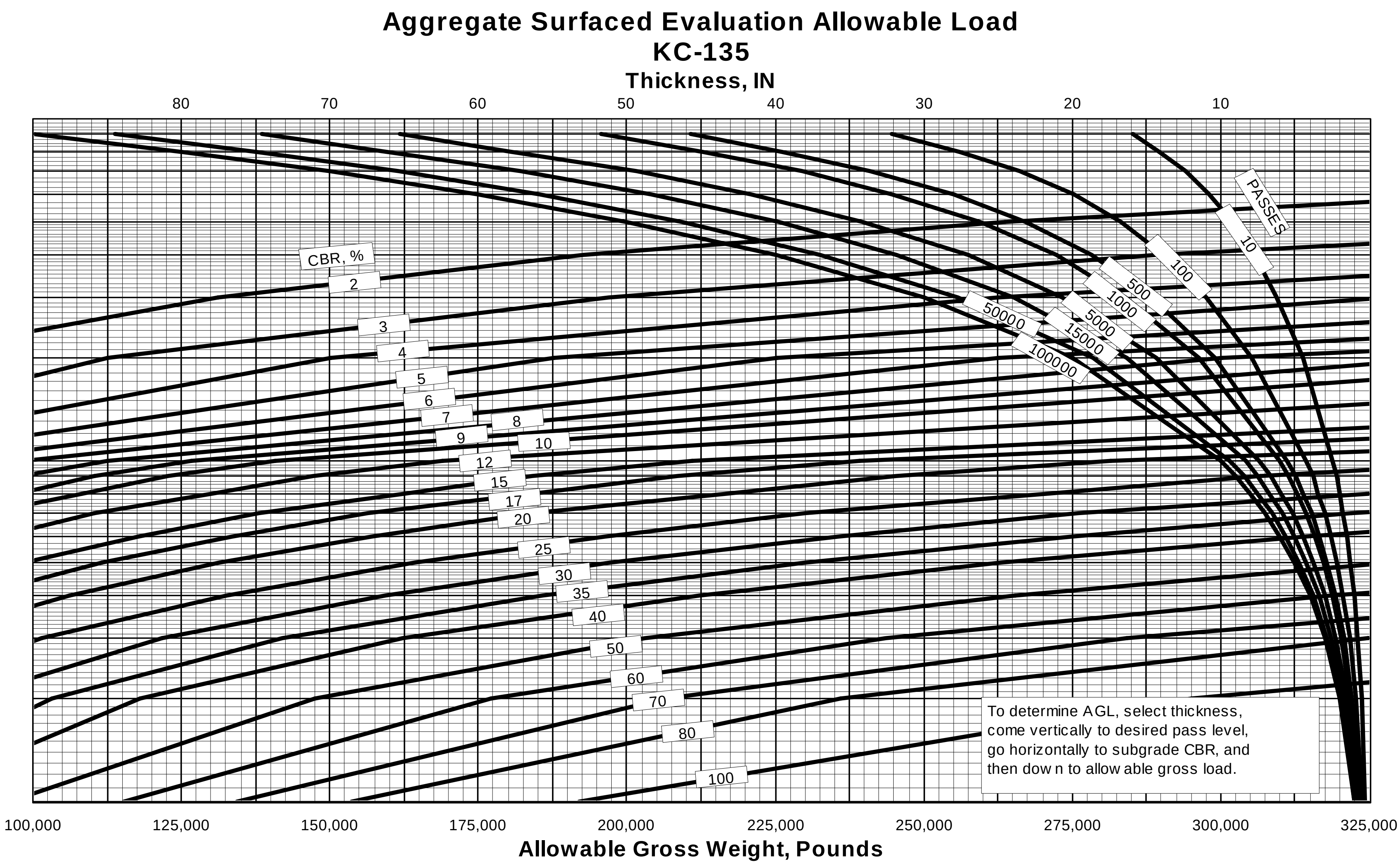
Soil Surface Strength Requirements
KC-10



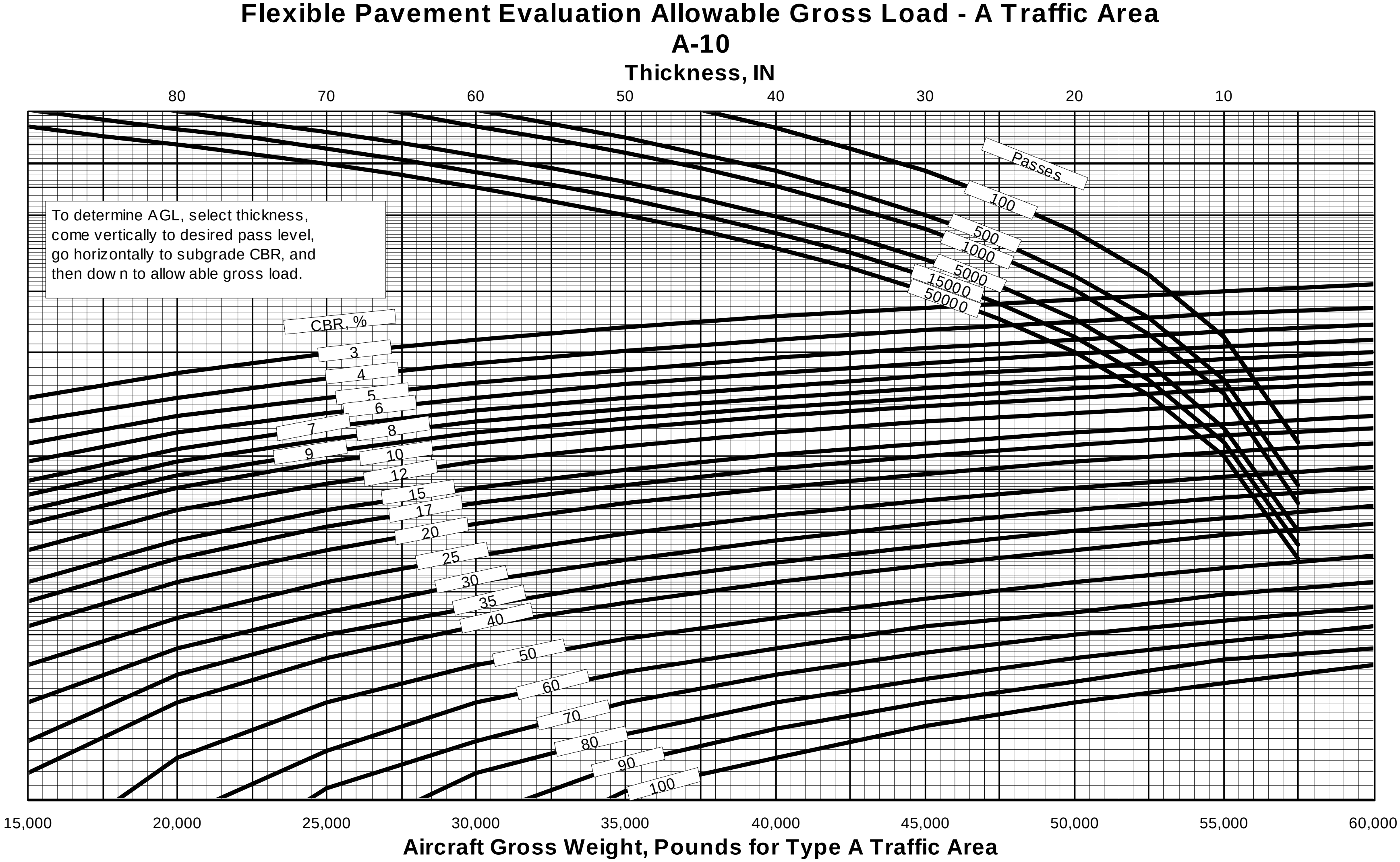
Aggregate Surfaced Evaluation Allowable Load
KC-10




Soil Surface Strength Requirements
KC-135
100
10
1
10
100
1,000
10,000
California Bearing Ratio (CBR), %
Aircraft Passes
Load, Pounds
301600
270000
220000
160000
104300
75000
To determine allow able passes, select thickness, come vertically to desired load, go horizontally to subgrade CBR, and then dow n to allow able passes.

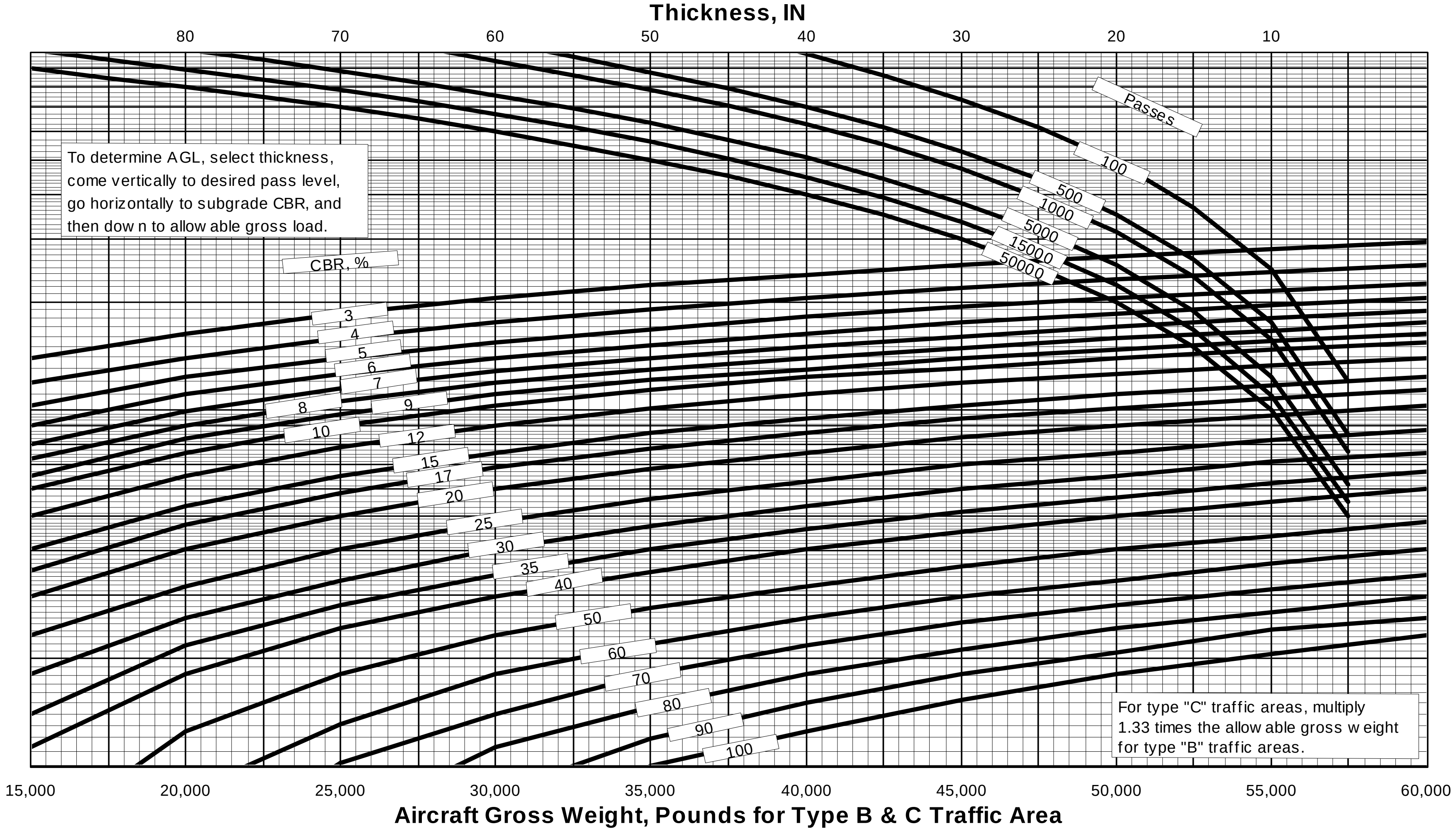

Aggregate Surfaced Evaluation Allowable Load
KC-135
Thickness, IN
80
70
60
50
40
30
20
10
PASSES
10
100
500
1000
5000
15000
50000
100000
CBR, %
2
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
100
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
100,000
125,000
150,000
175,000
200,000
225,000
250,000
275,000
300,000
325,000
Allowable Gross Weight, Pounds

Appendix C: Flexible Pavement Evaluation Curves

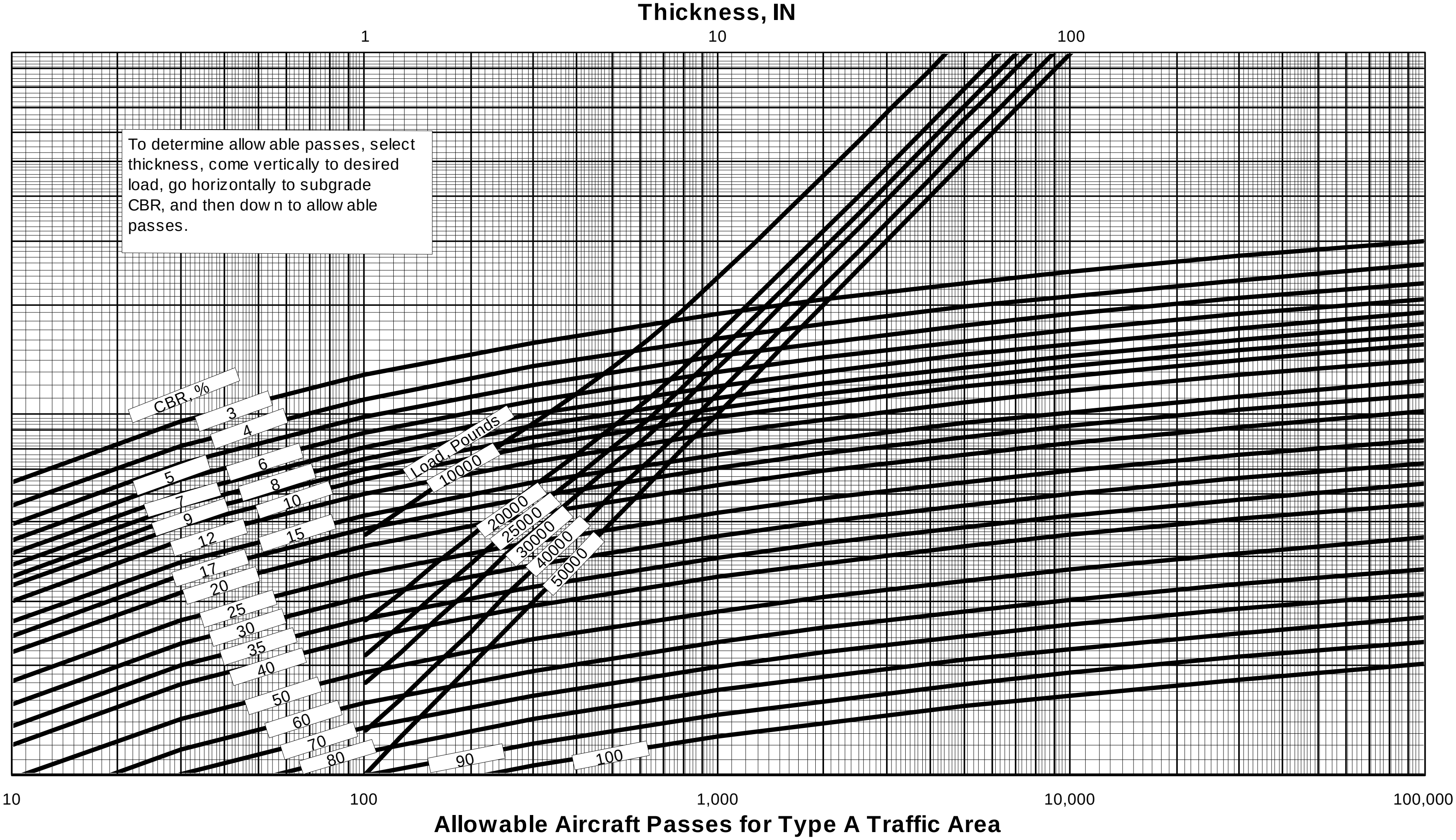


Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area

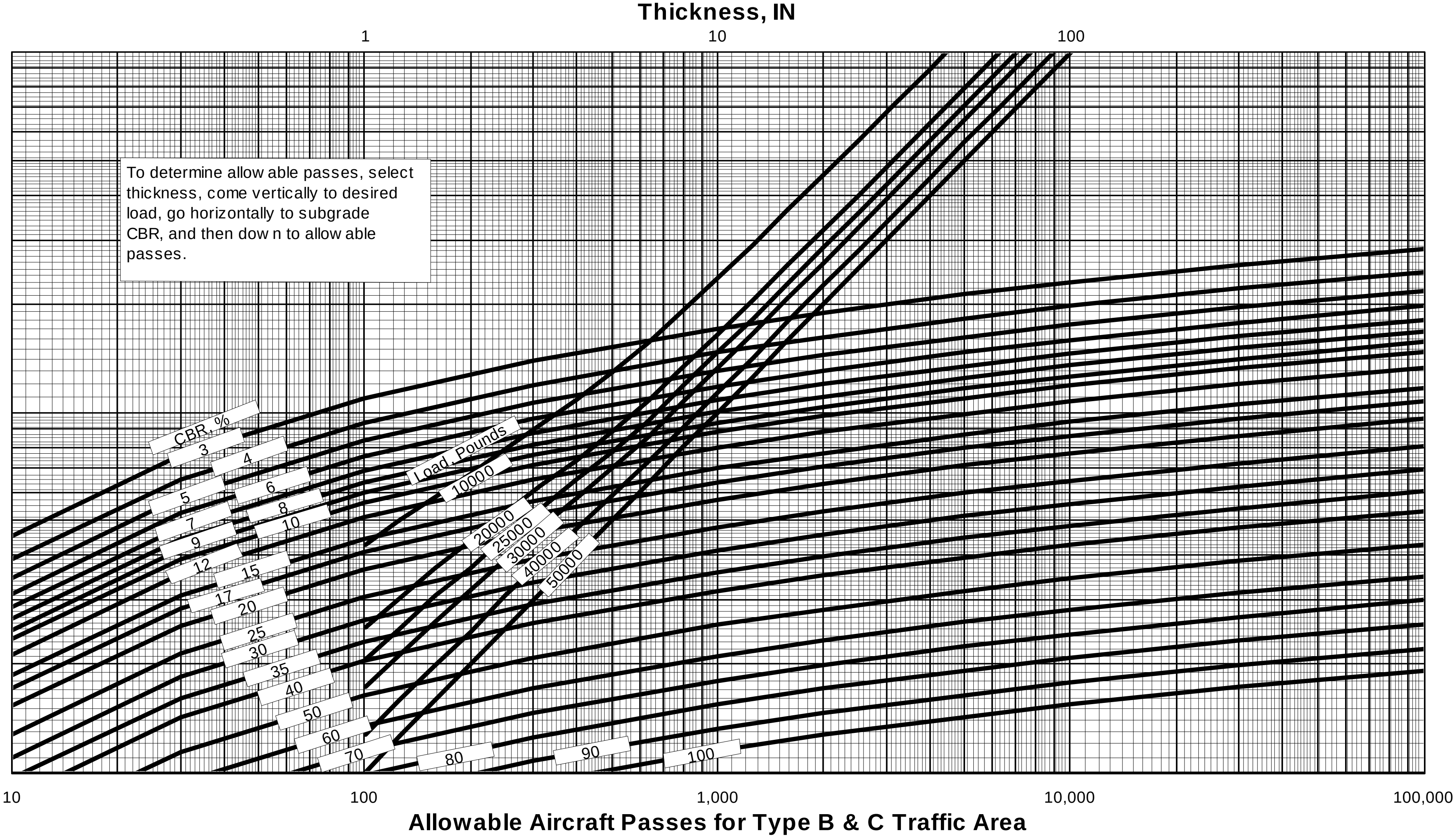
A-10

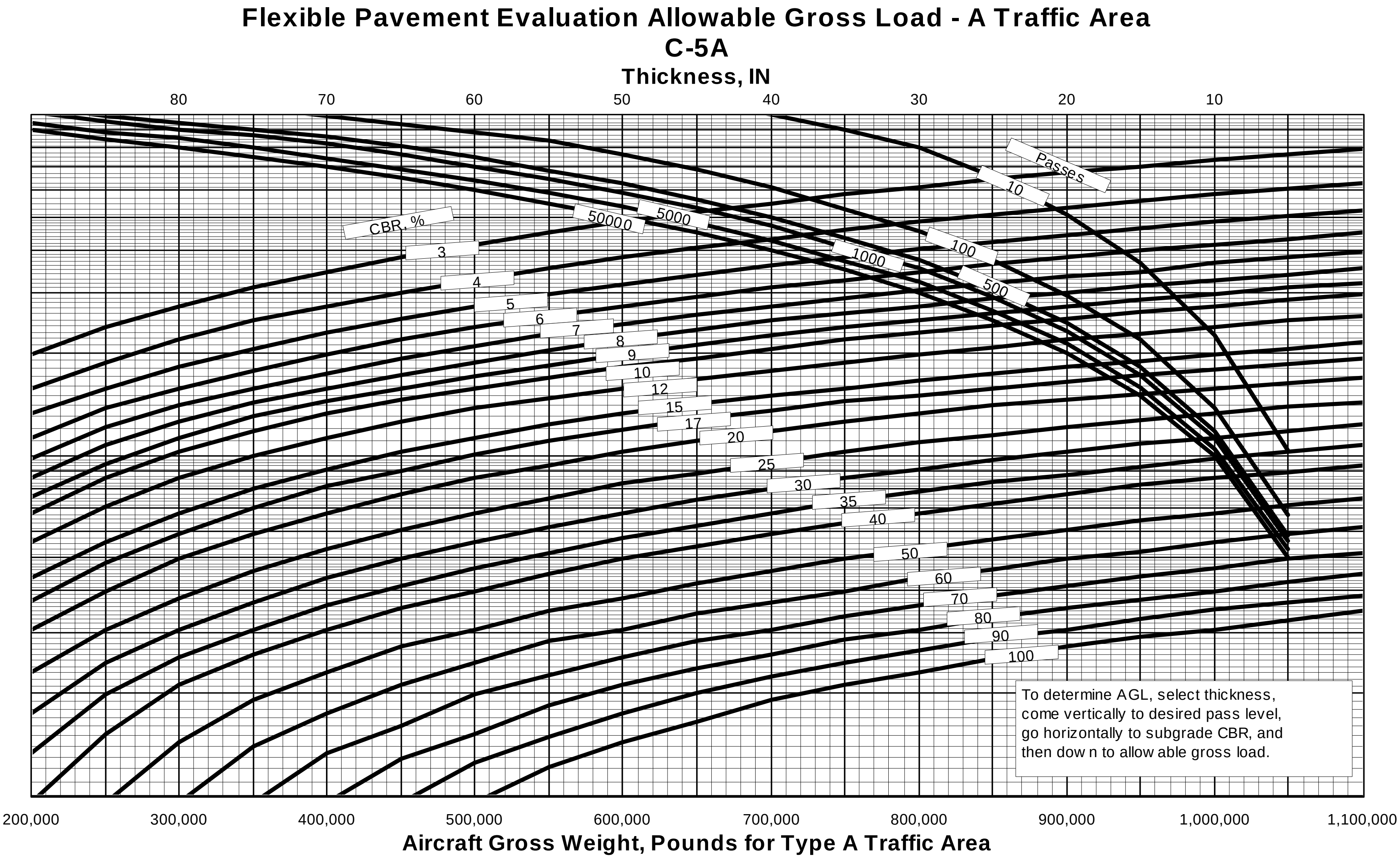


Flexible Pavement Evaluation Allowable Passes - A Traffic Area
A-10

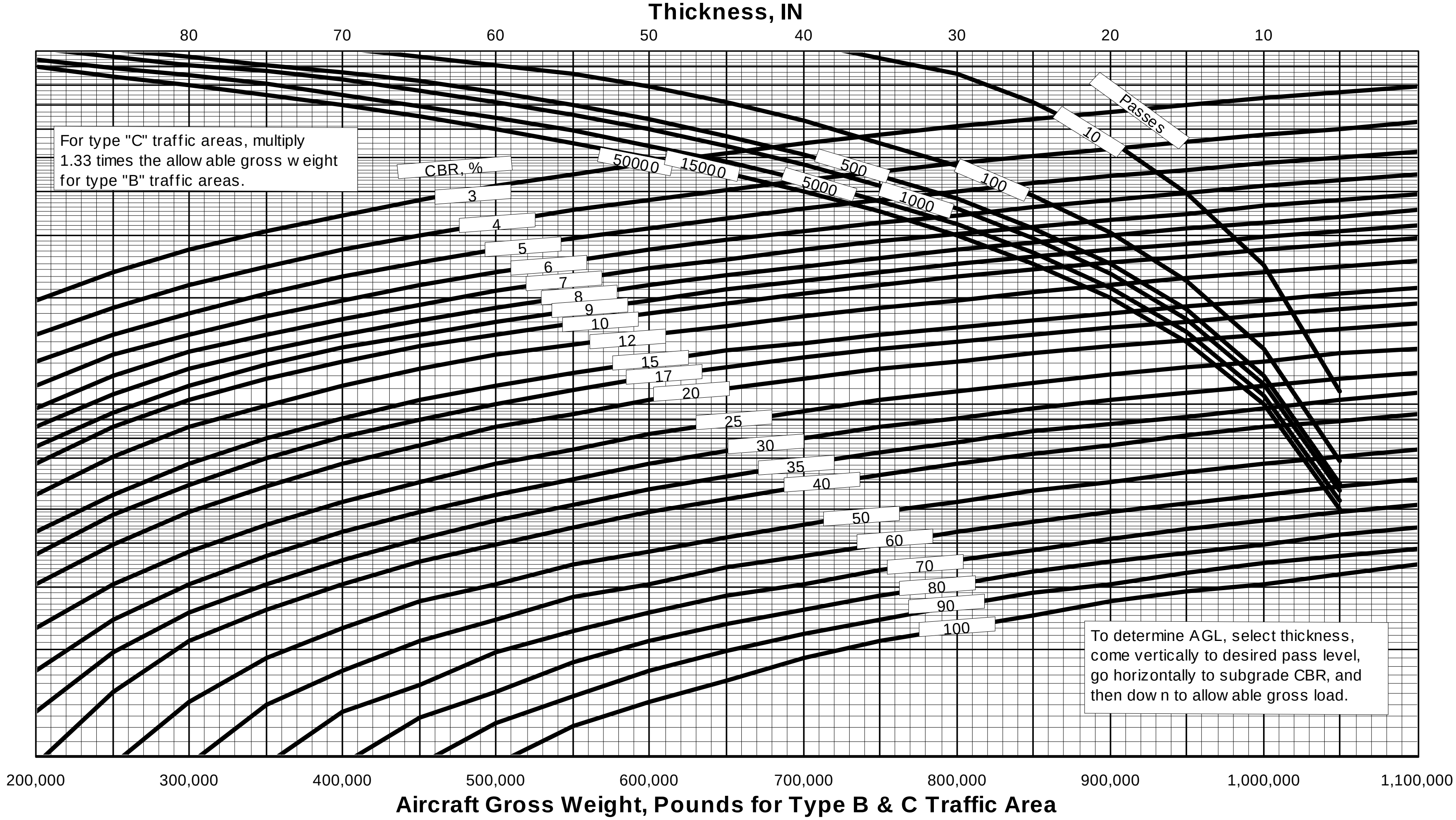


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
A-10

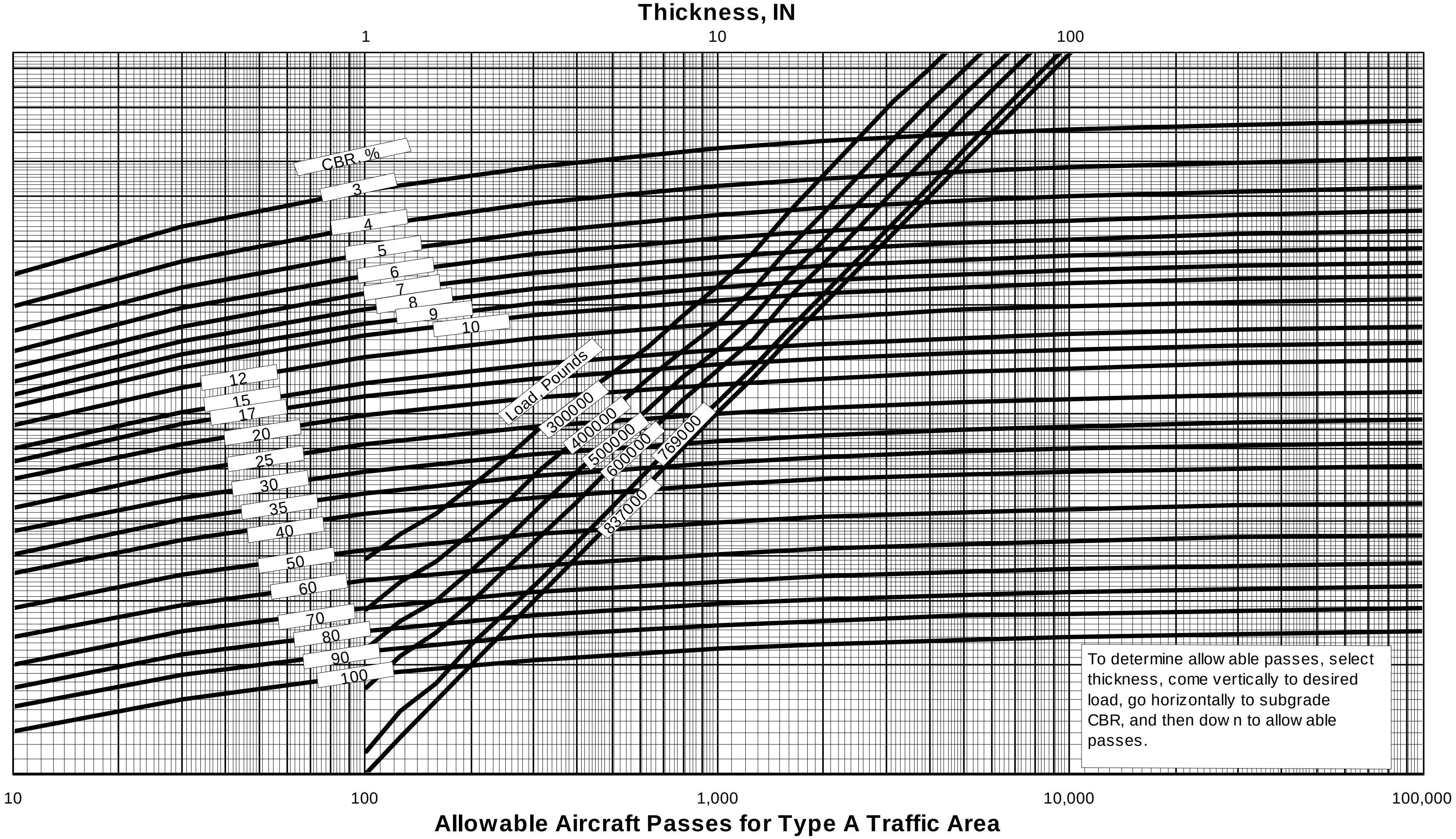



Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
C-5A
Thickness, IN
80
70
60
50
40
30
20
10
Passes
10
100
500
1000
5000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
Aircraft Gross Weight, Pounds for Type A Traffic Area

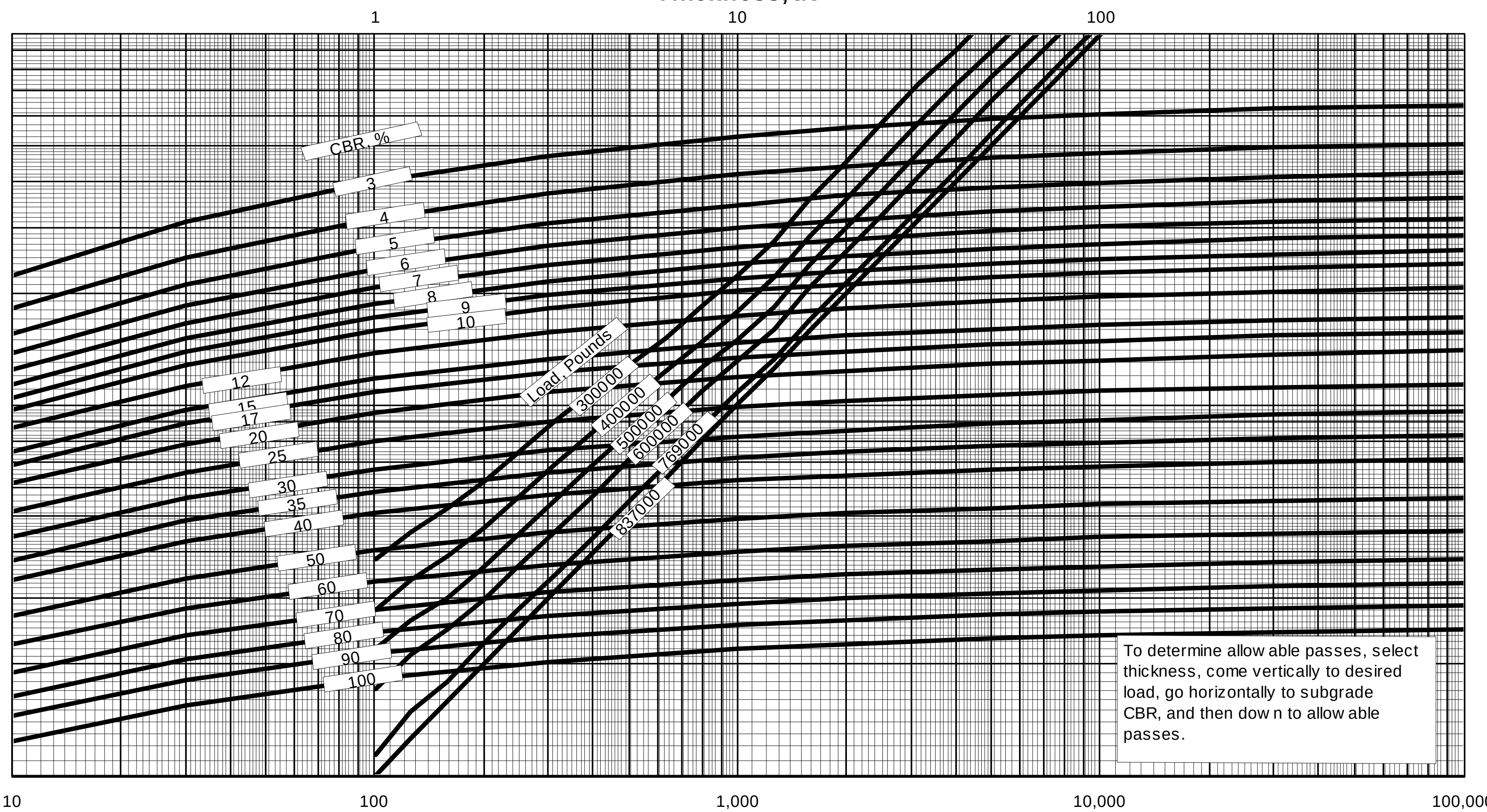
Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
C-5A

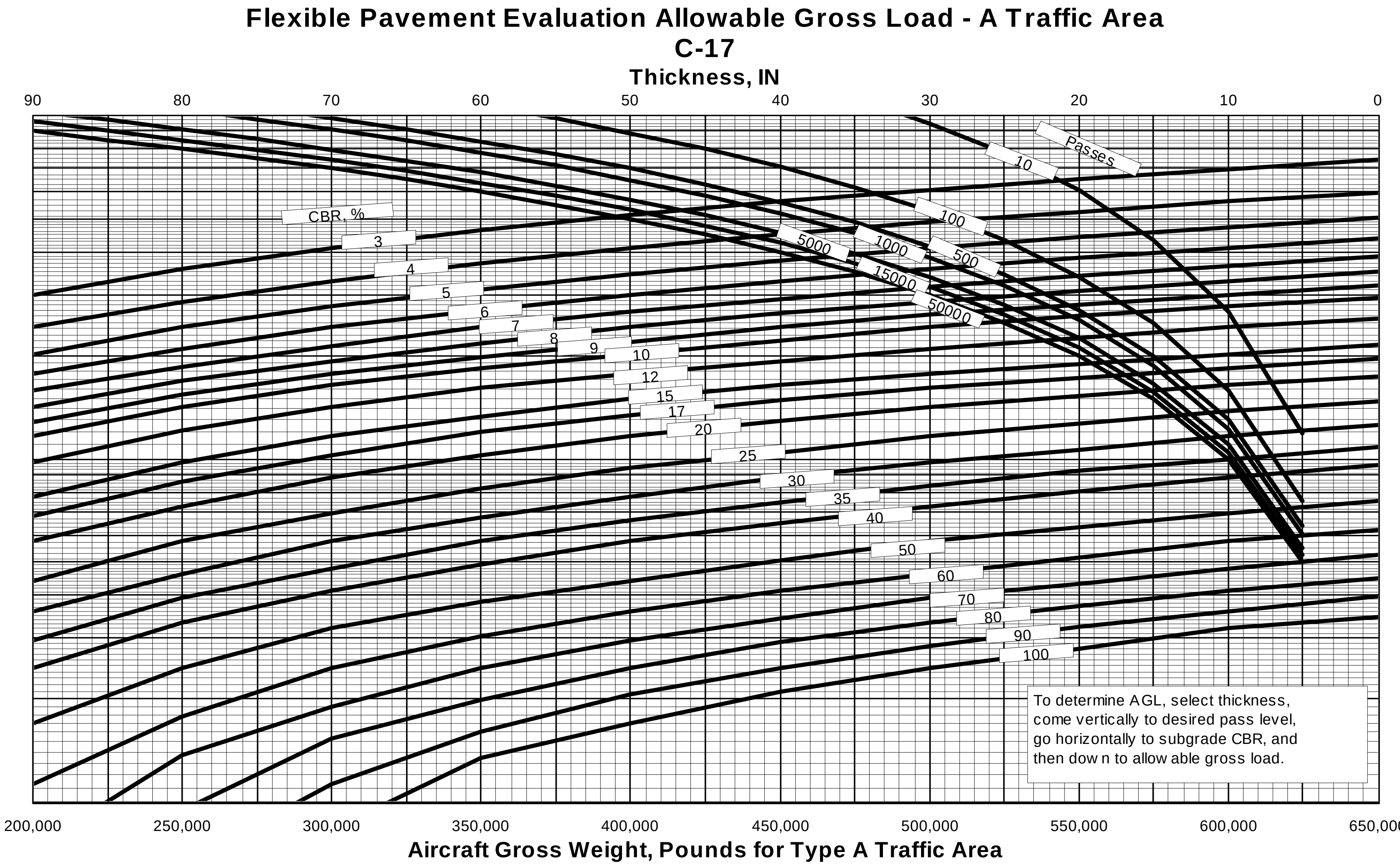


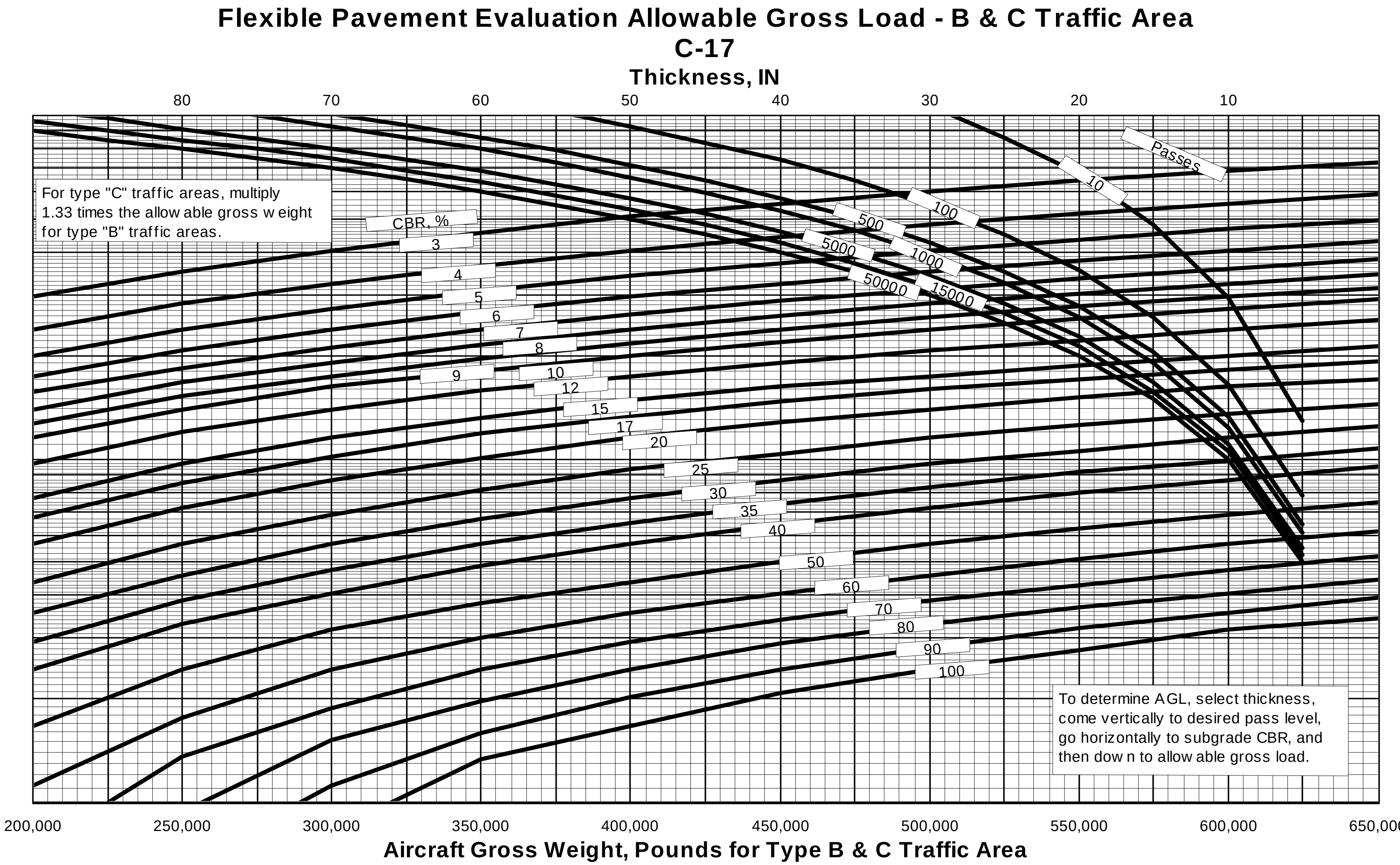
Flexible Pavement Evaluation Allowable Passes - A Traffic Area
C-5A



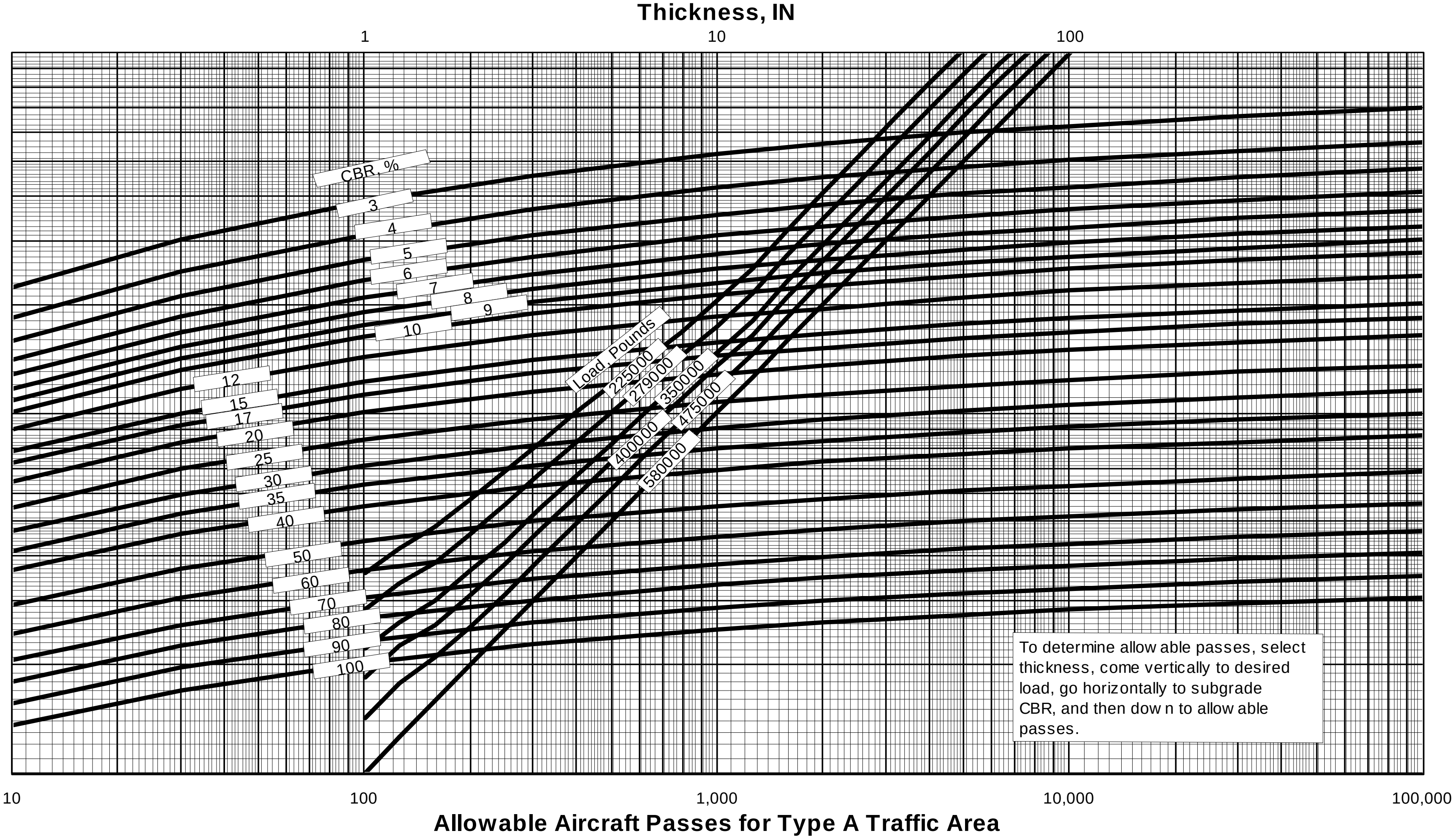
Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
C-5A



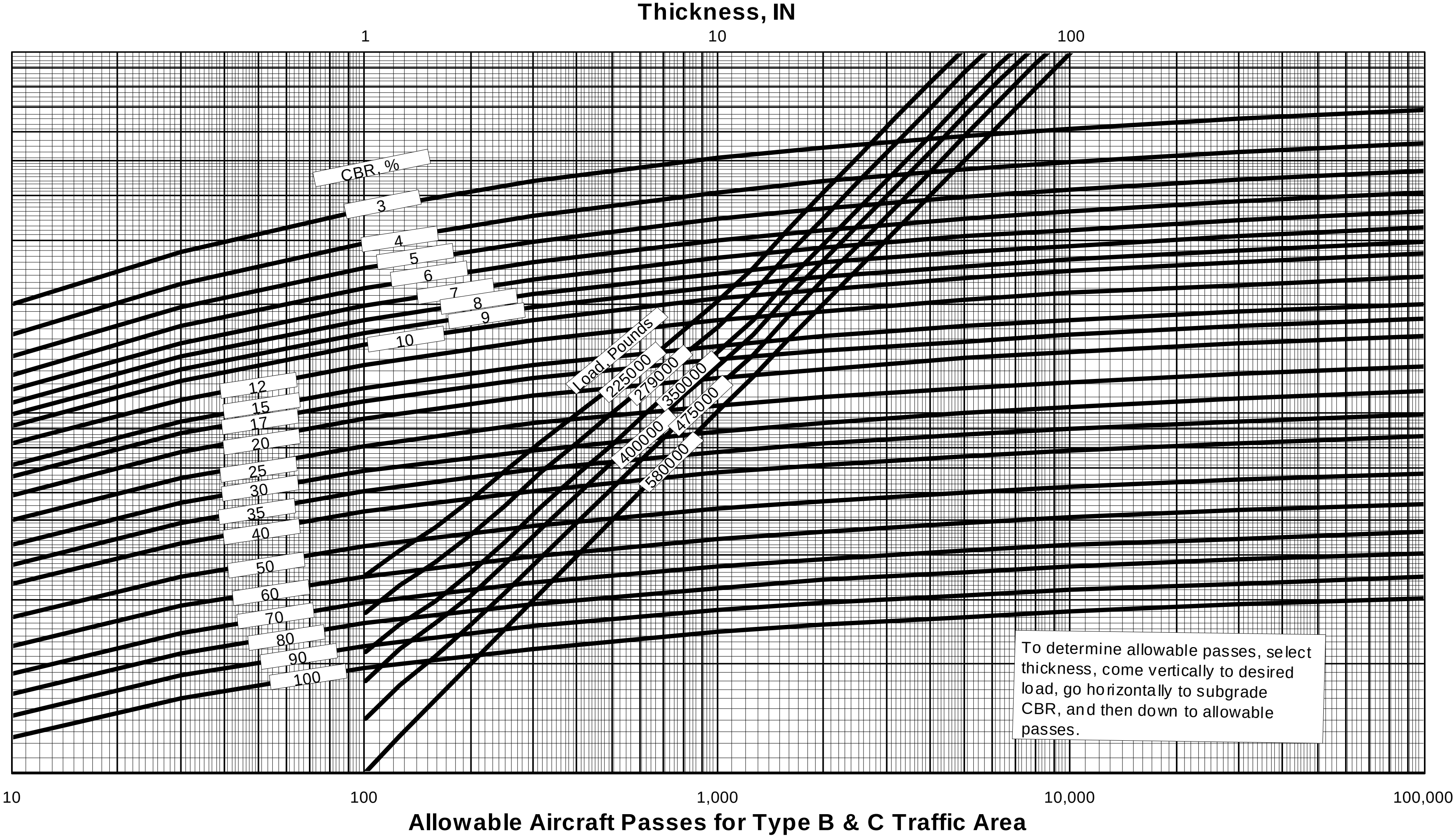

Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
C-17
Thickness, IN
90
80
70
60
50
40
30
20
10
0
Passes
10
100
500
1000
5000
15000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
200,000
250,000
300,000
350,000
400,000
450,000
500,000
550,000
600,000
650,000
Aircraft Gross Weight, Pounds for Type A Traffic Area


Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
C-17
Thickness, IN
80
70
60
50
40
30
20
10
For type "C" traffic areas, multiply 1.33 times the allow able gross w eight for type "B" traffic areas.
Passes
10
100
500
1000
5000
15000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
200,000
250,000
300,000
350,000
400,000
450,000
500,000
550,000
600,000
650,000
Aircraft Gross Weight, Pounds for Type B & C Traffic Area

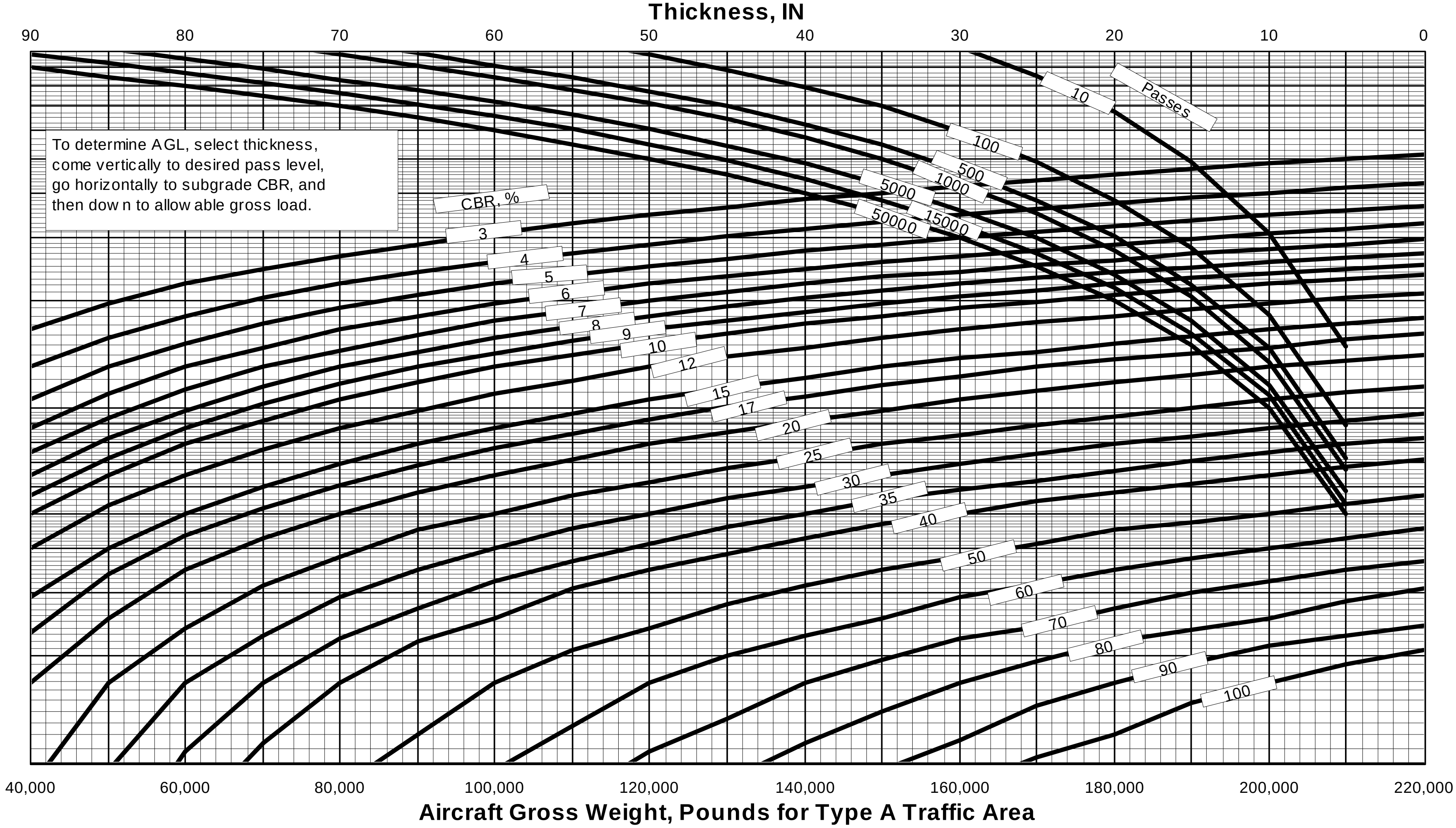
Flexible Pavement Evaluation Allowable Passes - A Traffic Area
C-17

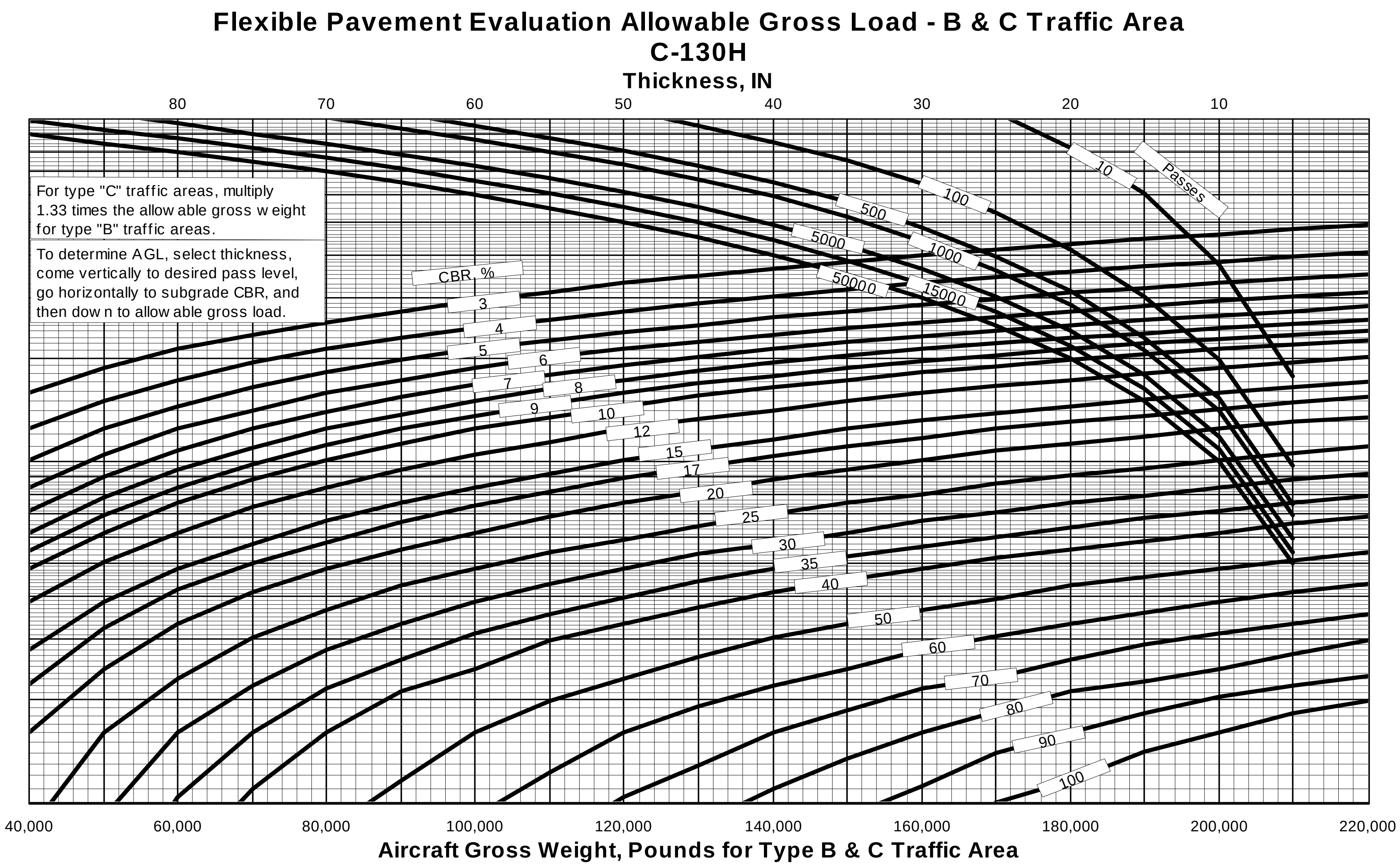


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
C-17

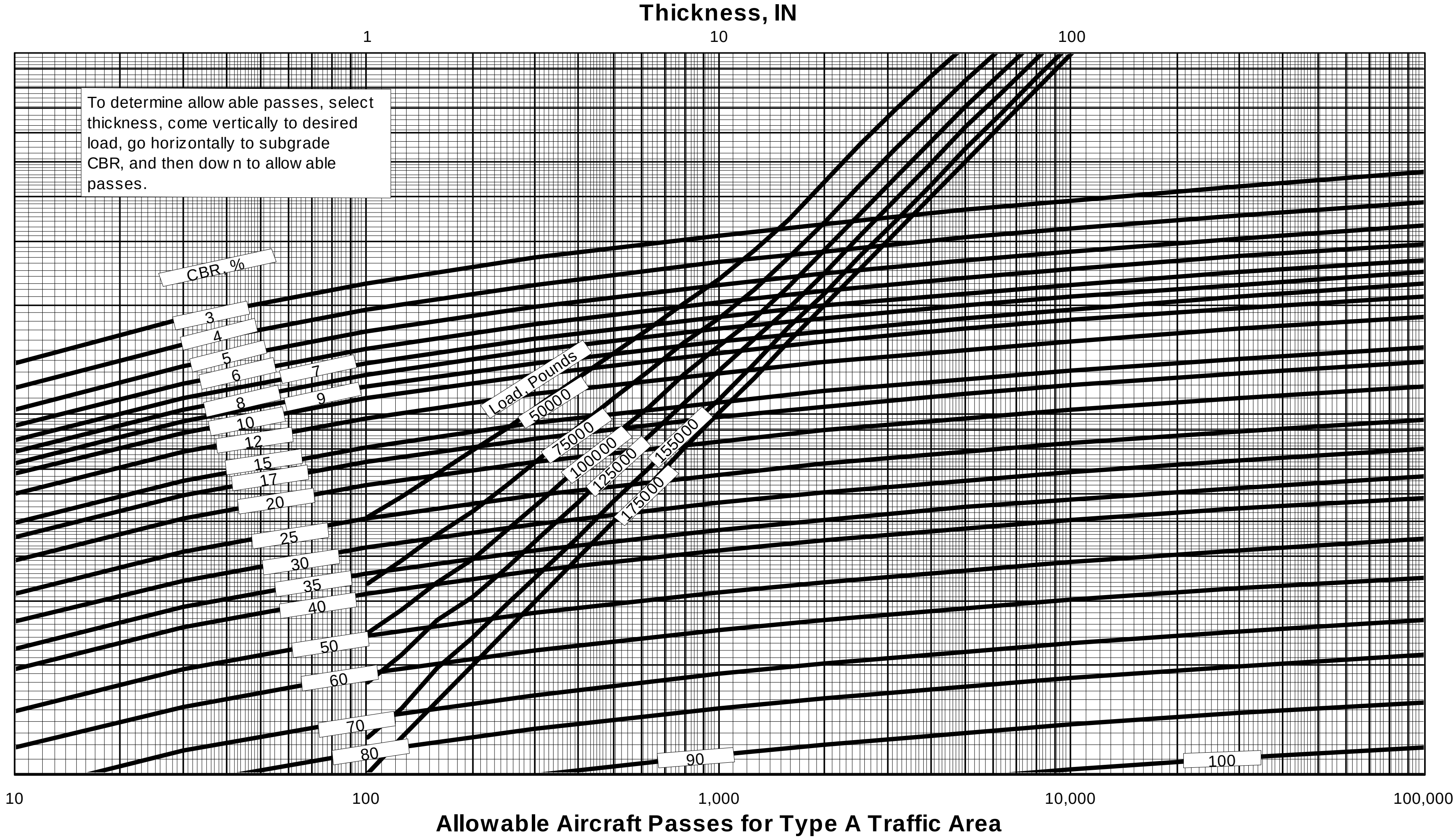


Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
C-130H

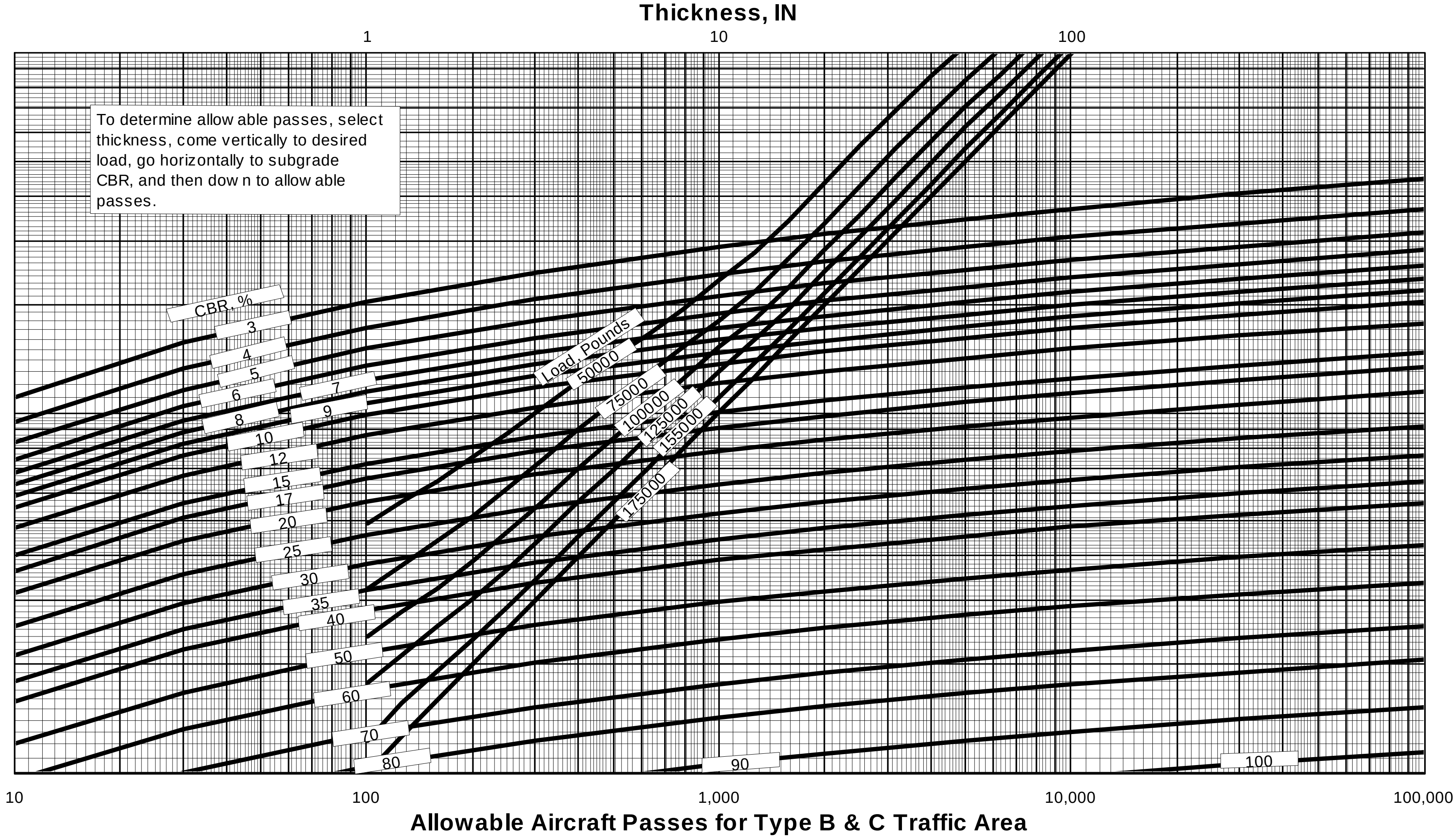



Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
C-130H
Thickness, IN
80
70
60
50
40
30
20
10
For type "C" traffic areas, multiply 1.33 times the allow able gross w eight for type "B" traffic areas.
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
Passes
10
100
500
1000
5000
15000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
220,000
Aircraft Gross Weight, Pounds for Type B & C Traffic Area

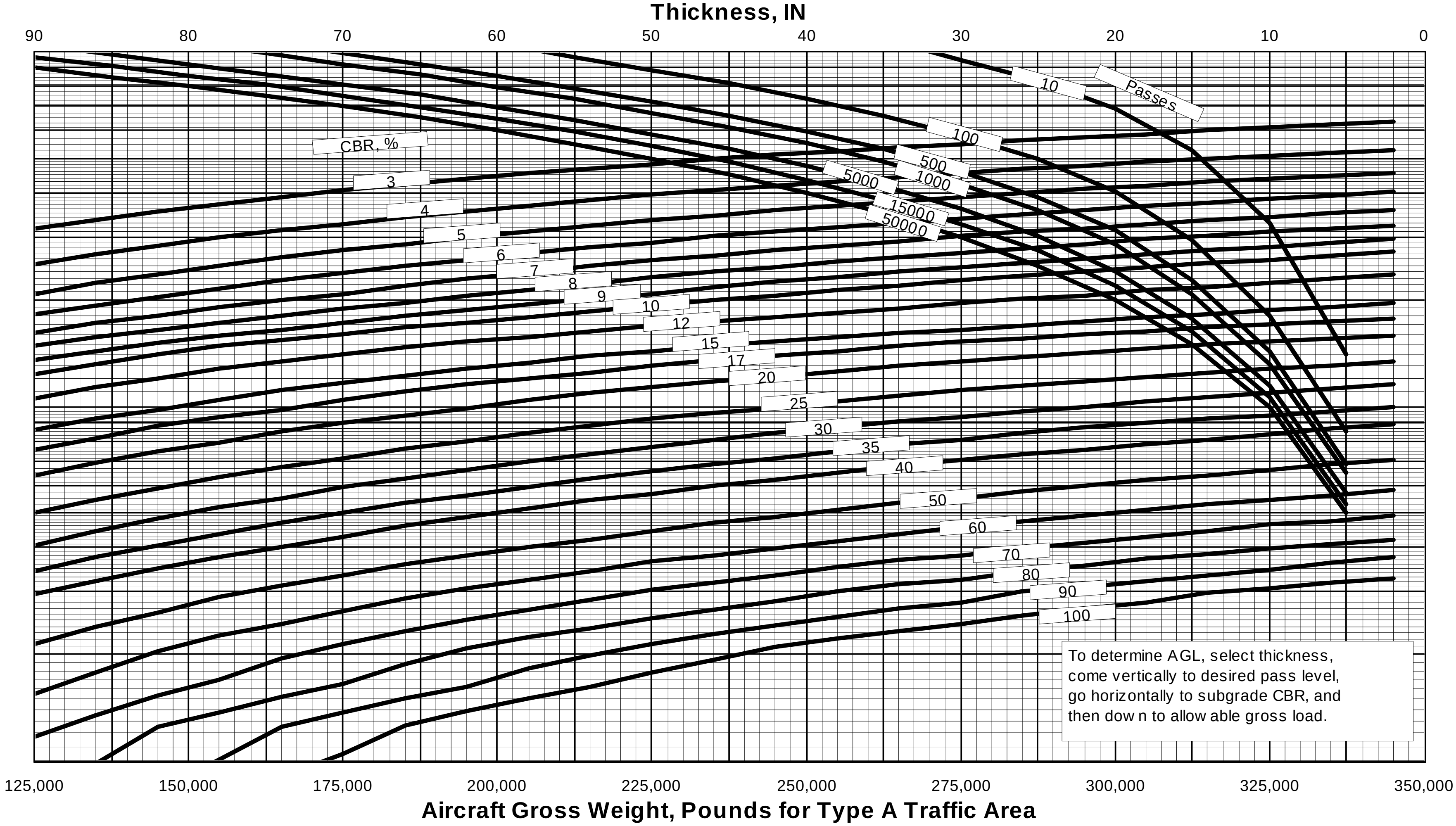
Flexible Pavement Evaluation Allowable Passes - A Traffic Area
C-130H



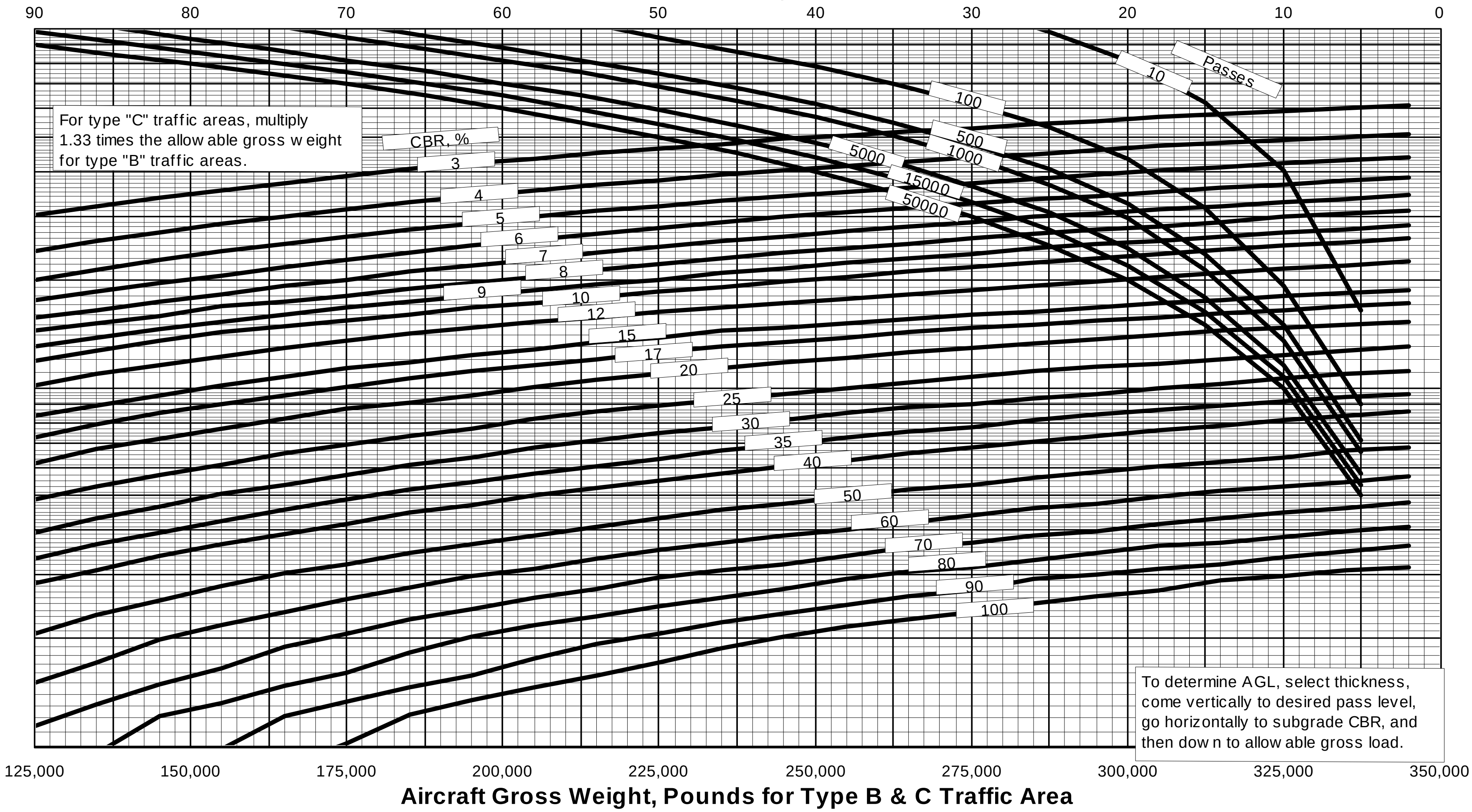
Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
C-130H



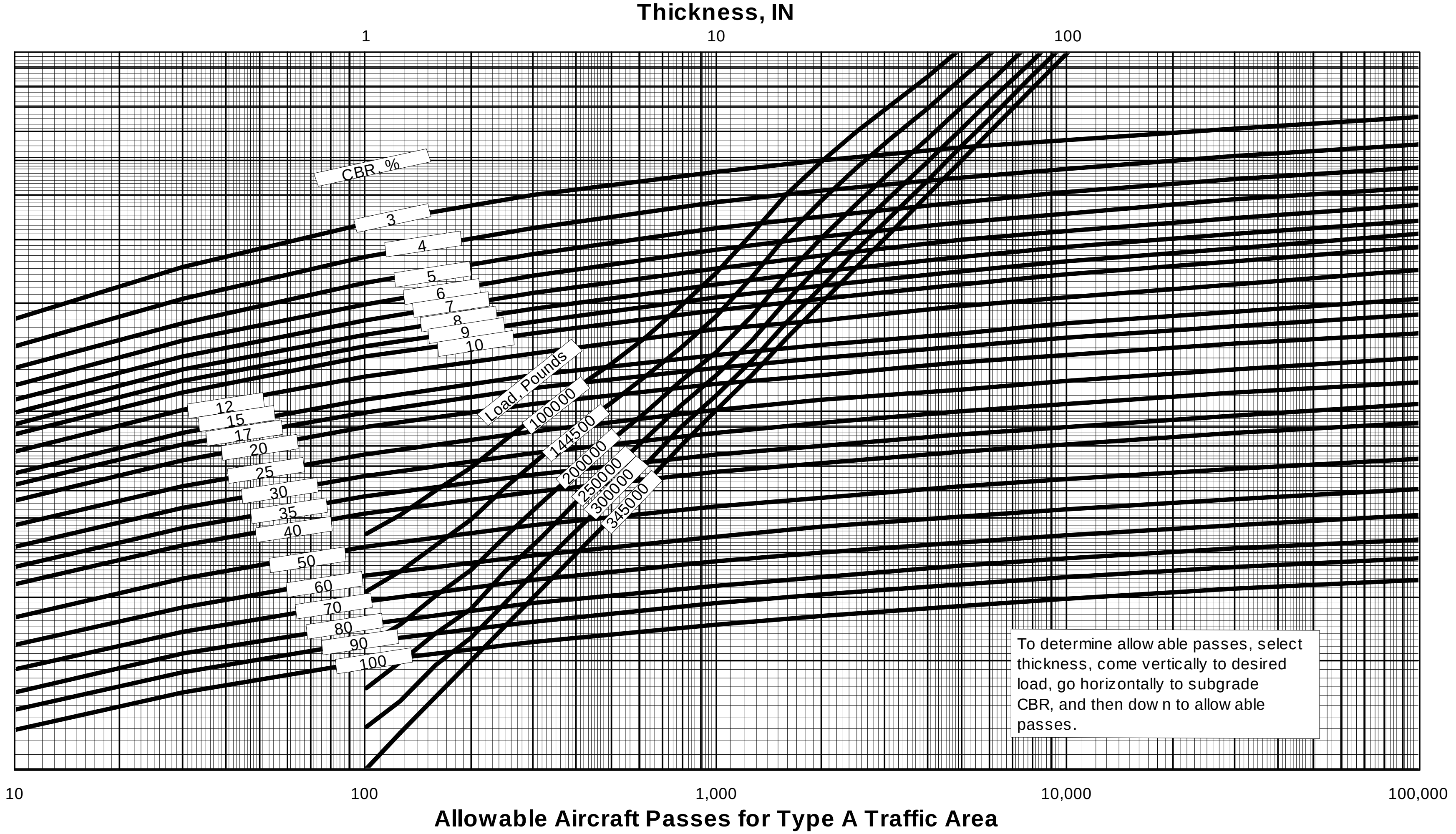
Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
C-141

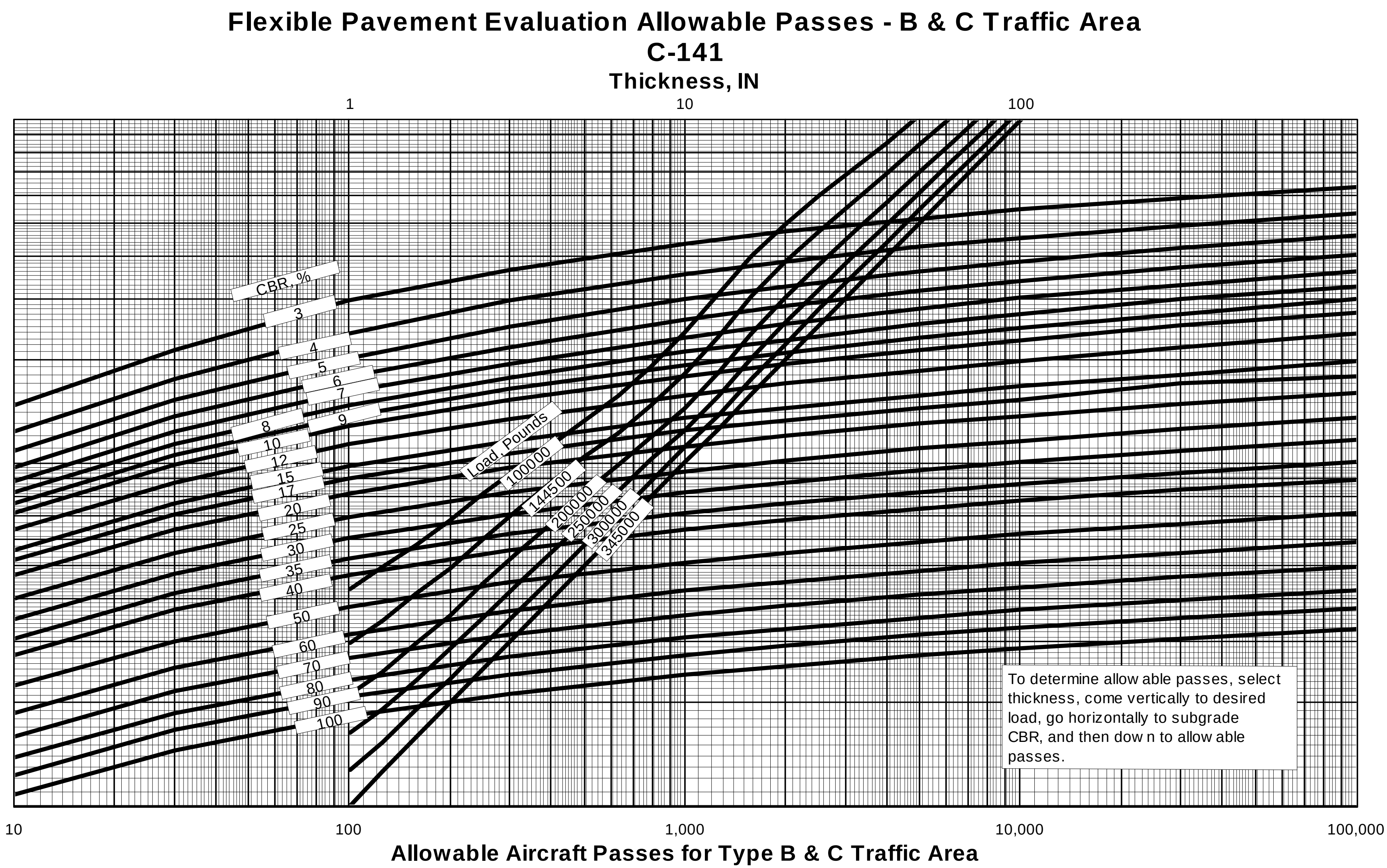


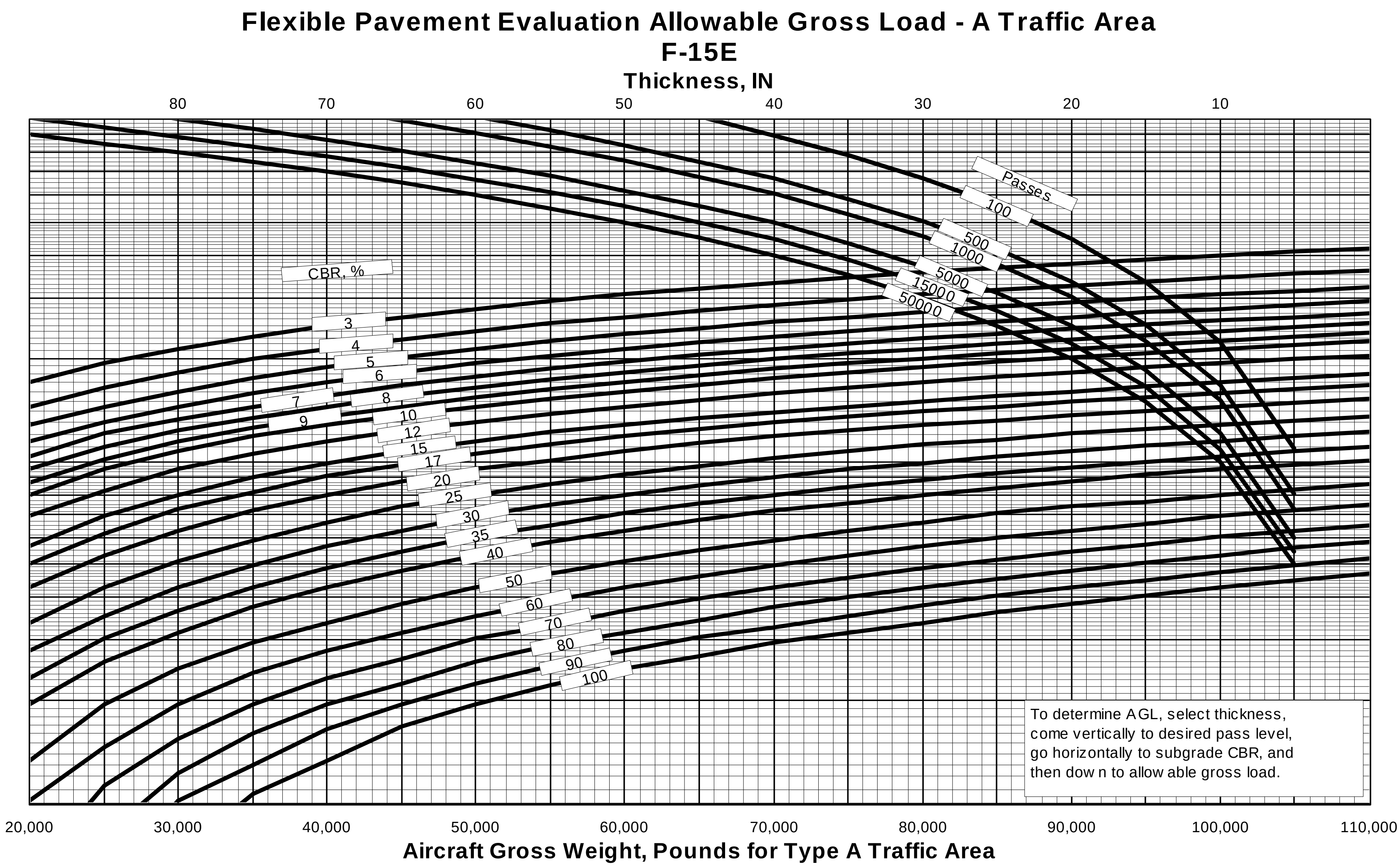
Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
C-141



Flexible Pavement Evaluation Allowable Passes - A Traffic Area
C-141

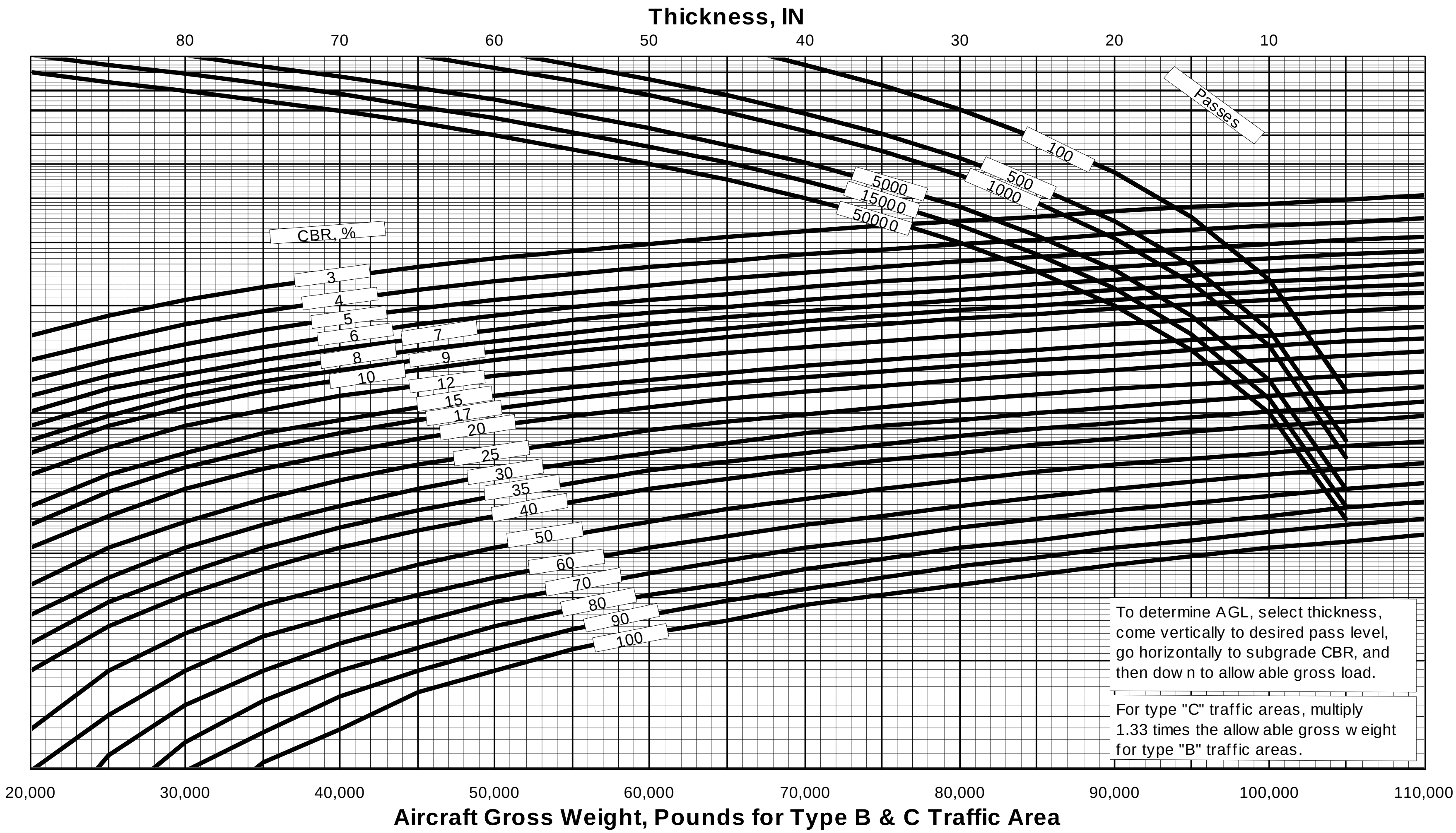



Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
C-141
Thickness, IN
1
10
100
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
Load, Pounds
100000
144500
200000
250000
300000
345000
To determine allow able passes, select thickness, come vertically to desired load, go horizontally to subgrade CBR, and then dow n to allow able passes.
10
100
1,000
10,000
100,000
Allowable Aircraft Passes for Type B & C Traffic Area

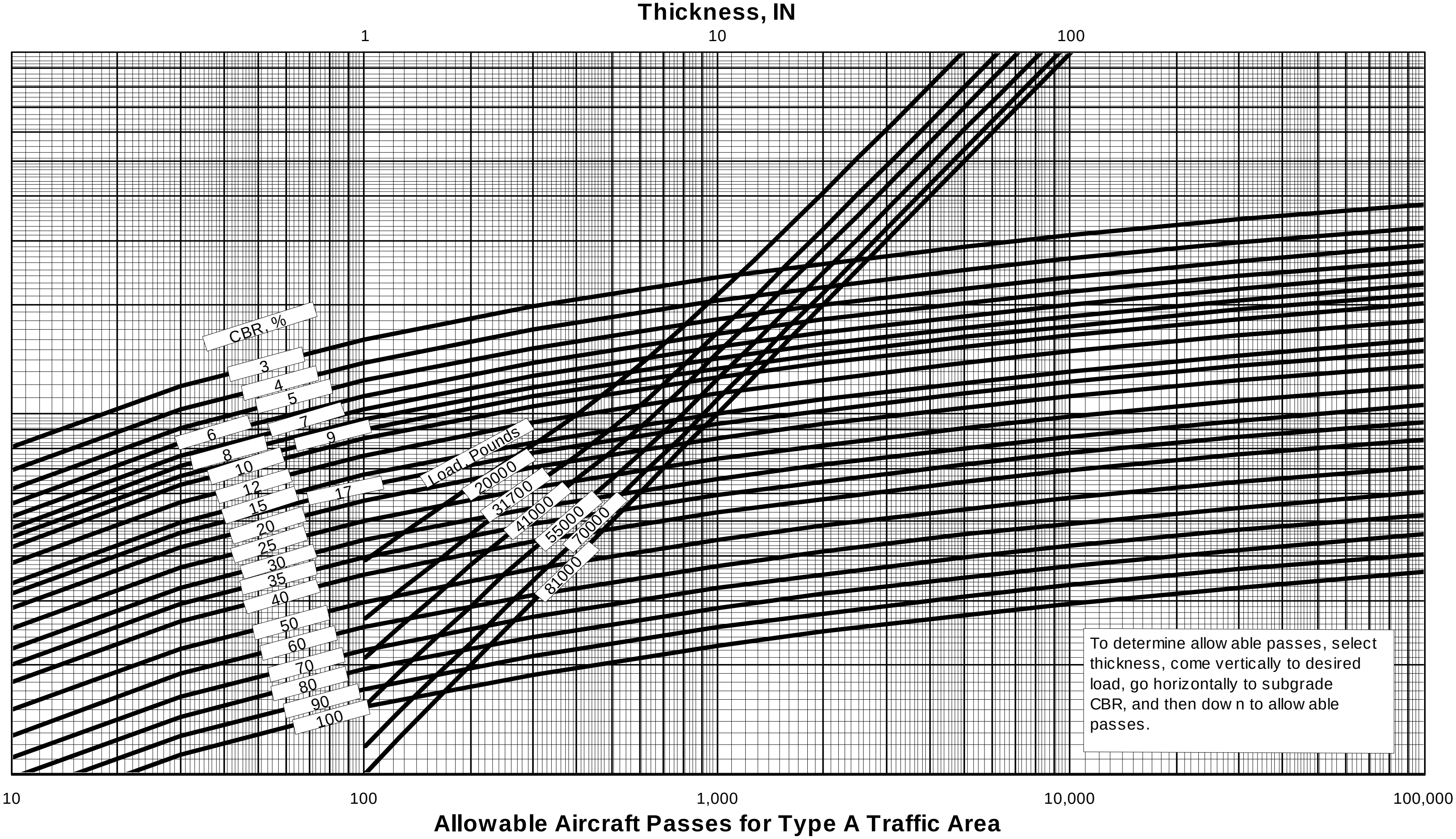


Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
F-15E
Thickness, IN
80
70
60
50
40
30
20
10
Passes
100
500
1000
5000
15000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then dow n to allow able gross load.
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
Aircraft Gross Weight, Pounds for Type A Traffic Area

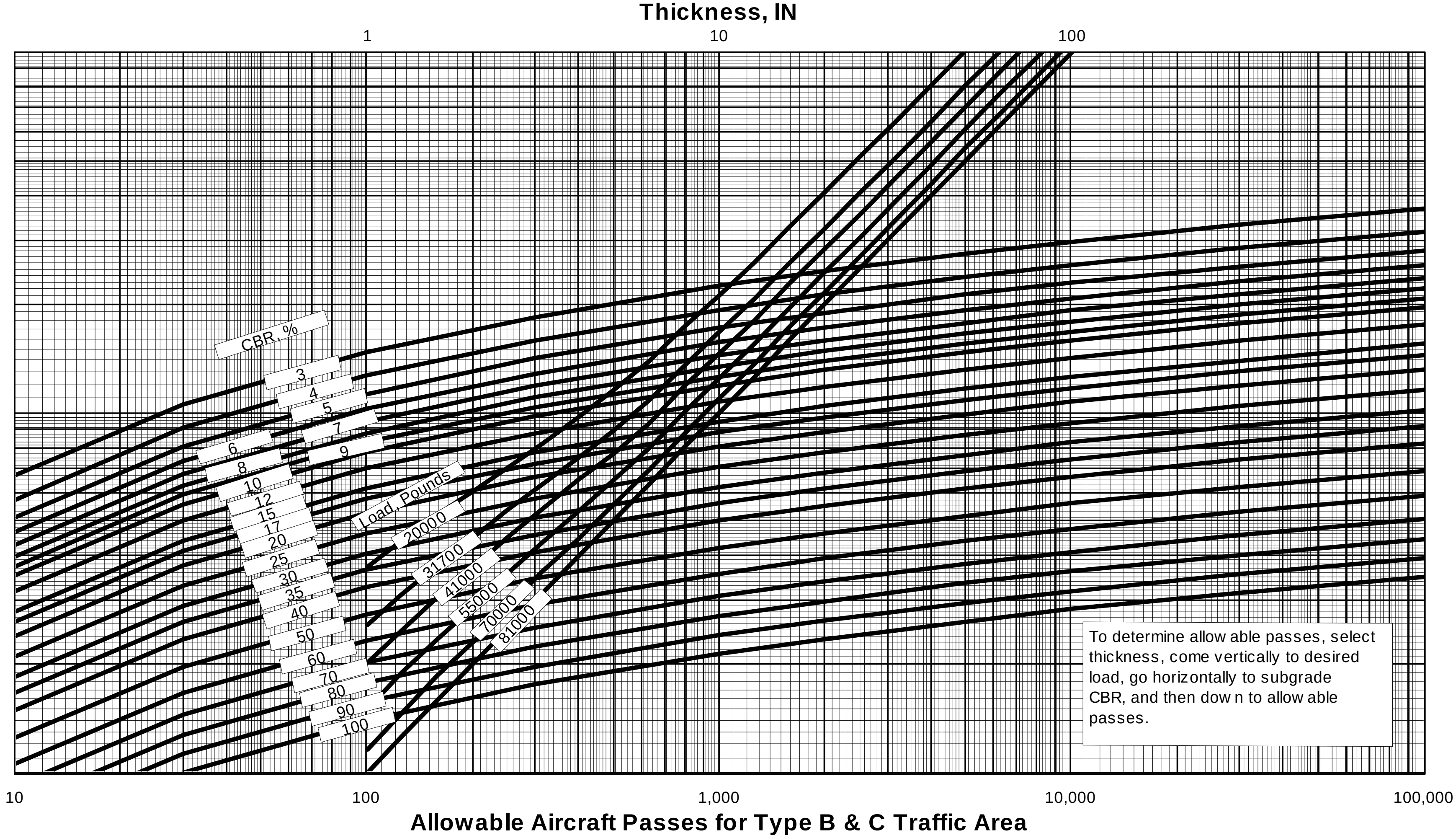
Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
F-15E



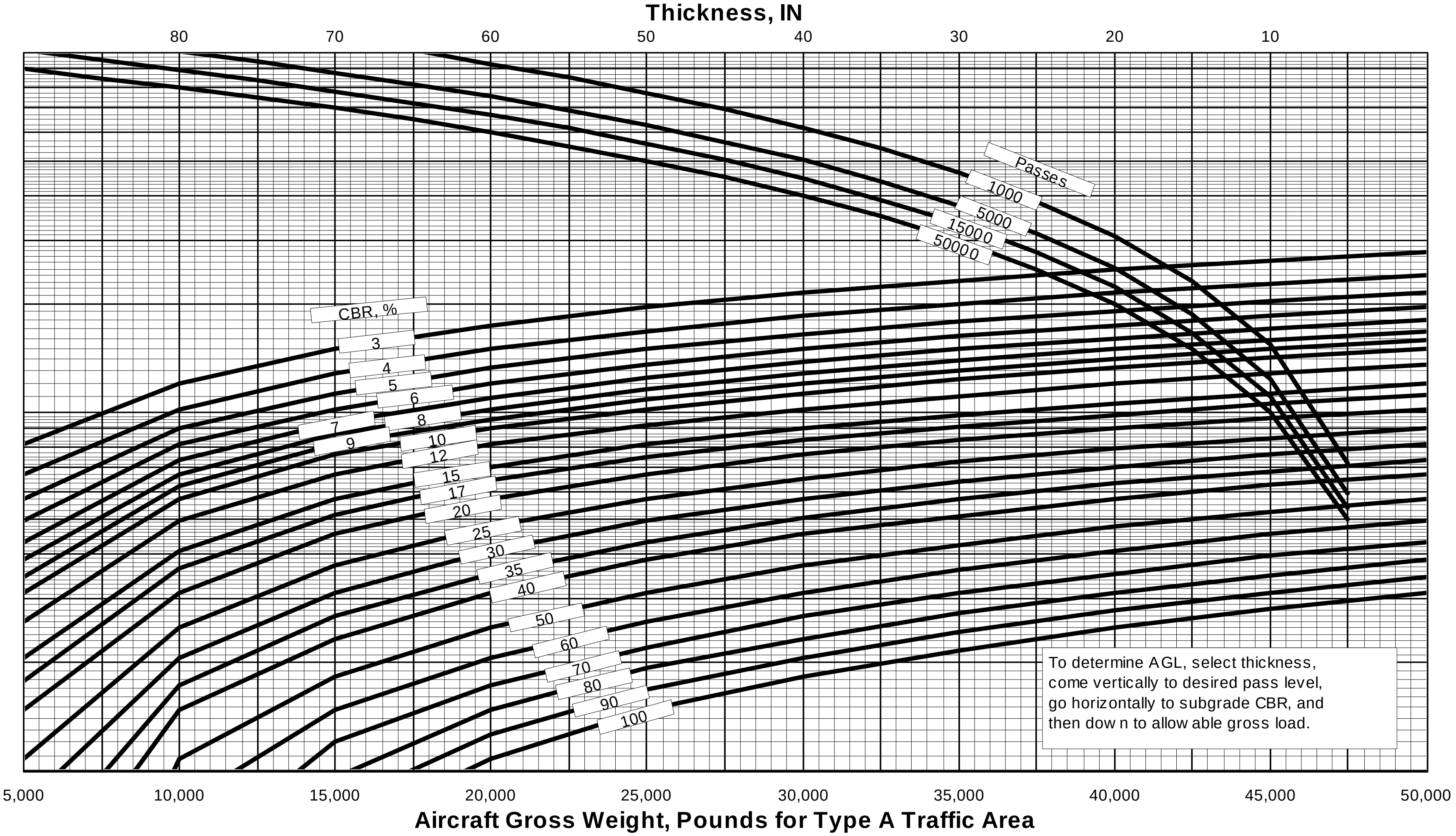
Flexible Pavement Evaluation Allowable Passes - A Traffic Area
F-15E

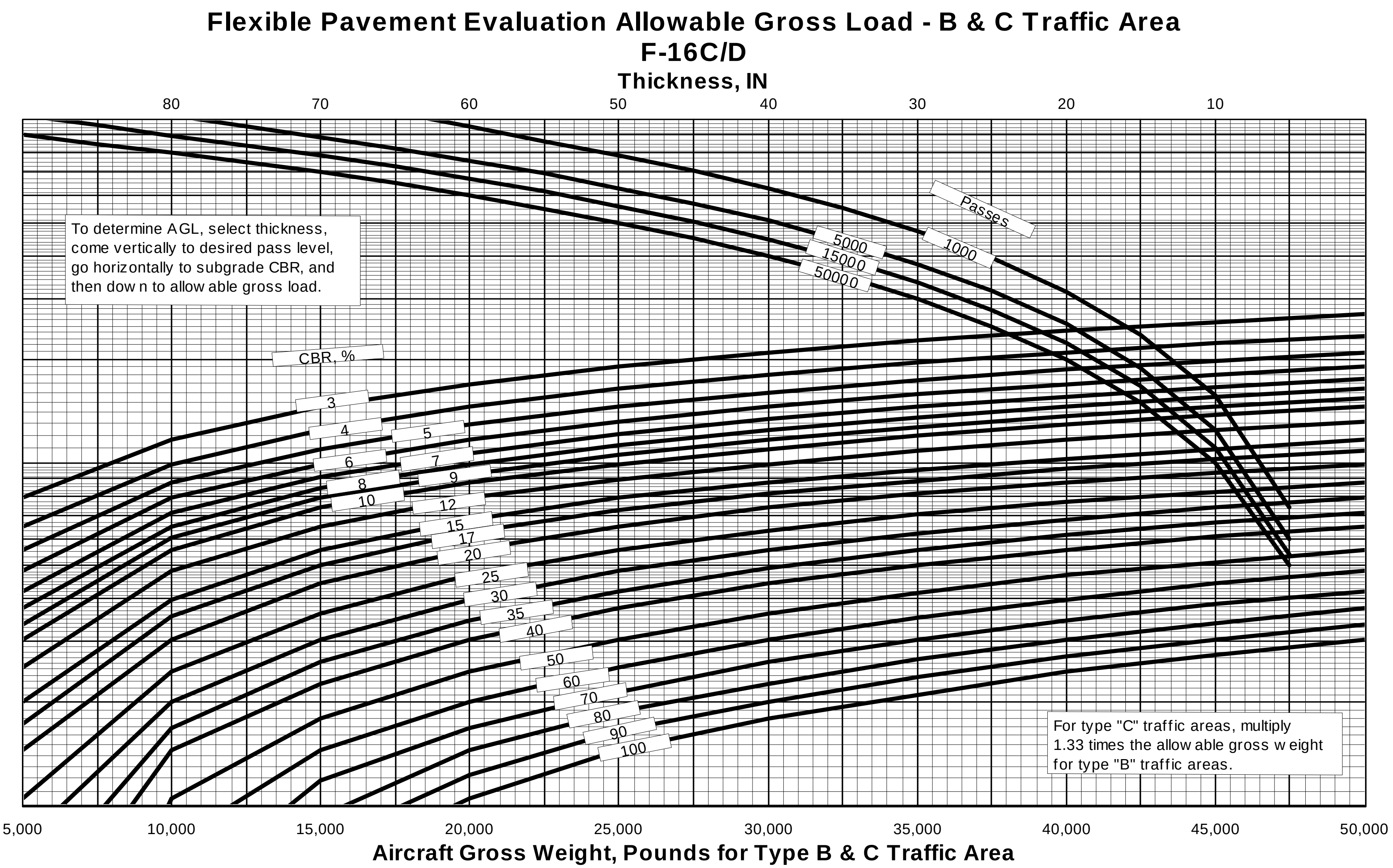


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
F-15E

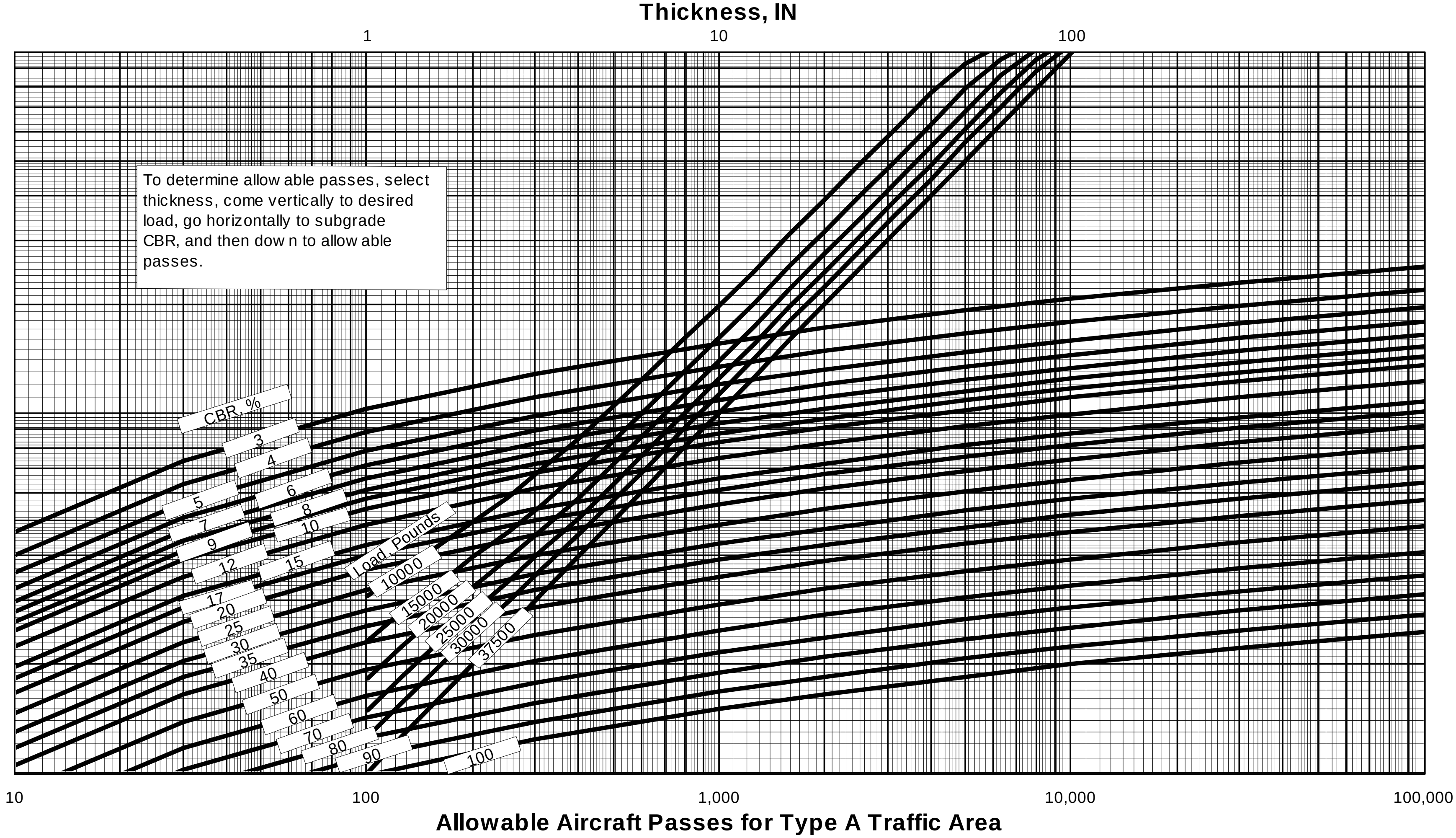


Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
F-16C/D

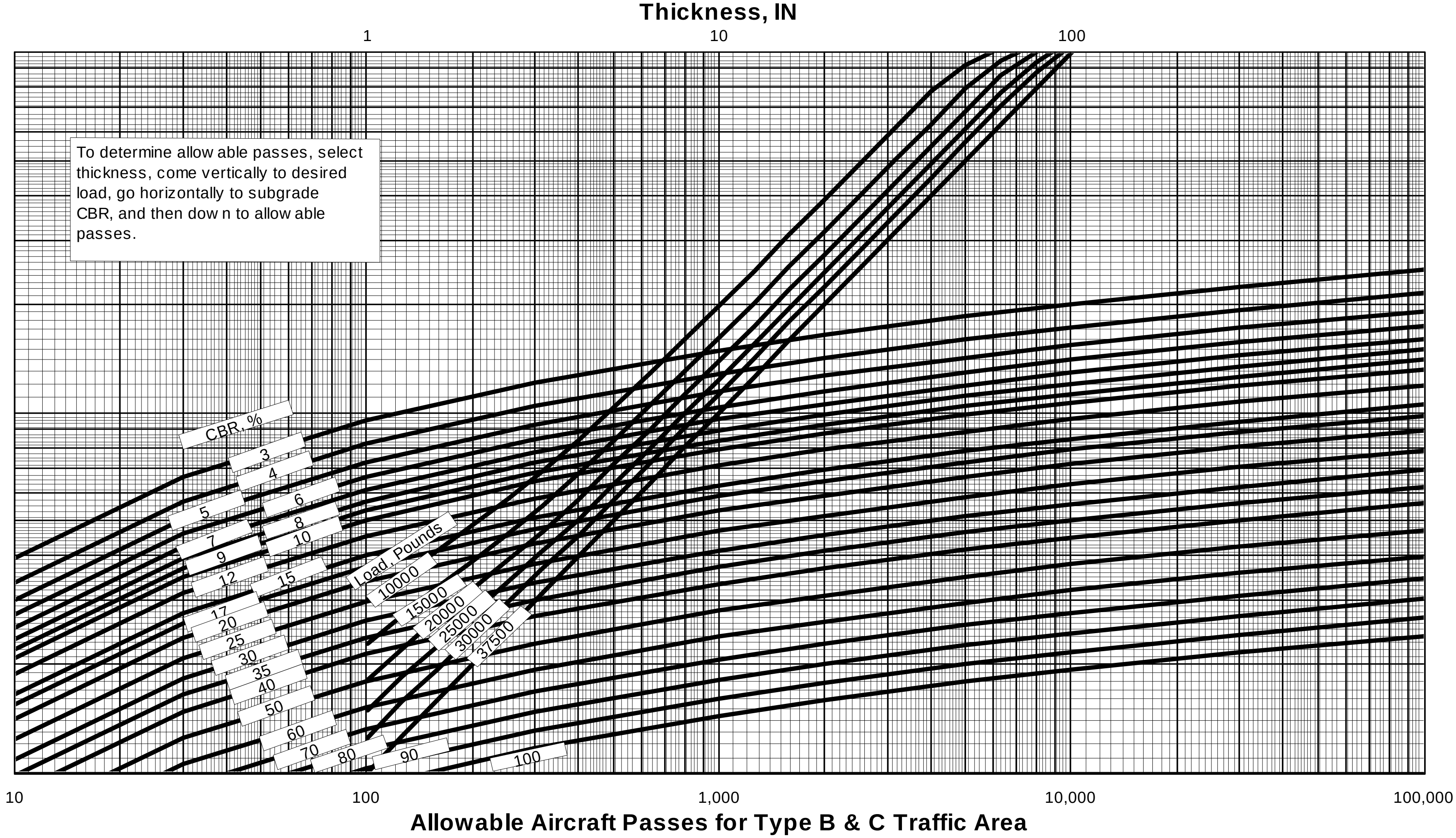



Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
F-16C/D
Thickness, IN
80
70
60
50
40
30
20
10
To determine AGL, select thickness, come vertically to desired pass level, go horizontally to subgrade CBR, and then down to allowable gross load.
Passes
1000
5000
15000
50000
CBR, %
3
4
5
6
7
8
9
10
12
15
17
20
25
30
35
40
50
60
70
80
90
100
For type "C" traffic areas, multiply 1.33 times the allowable gross weight for type "B" traffic areas.
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Aircraft Gross Weight, Pounds for Type B & C Traffic Area

Flexible Pavement Evaluation Allowable Passes - A Traffic Area
F-16C/D

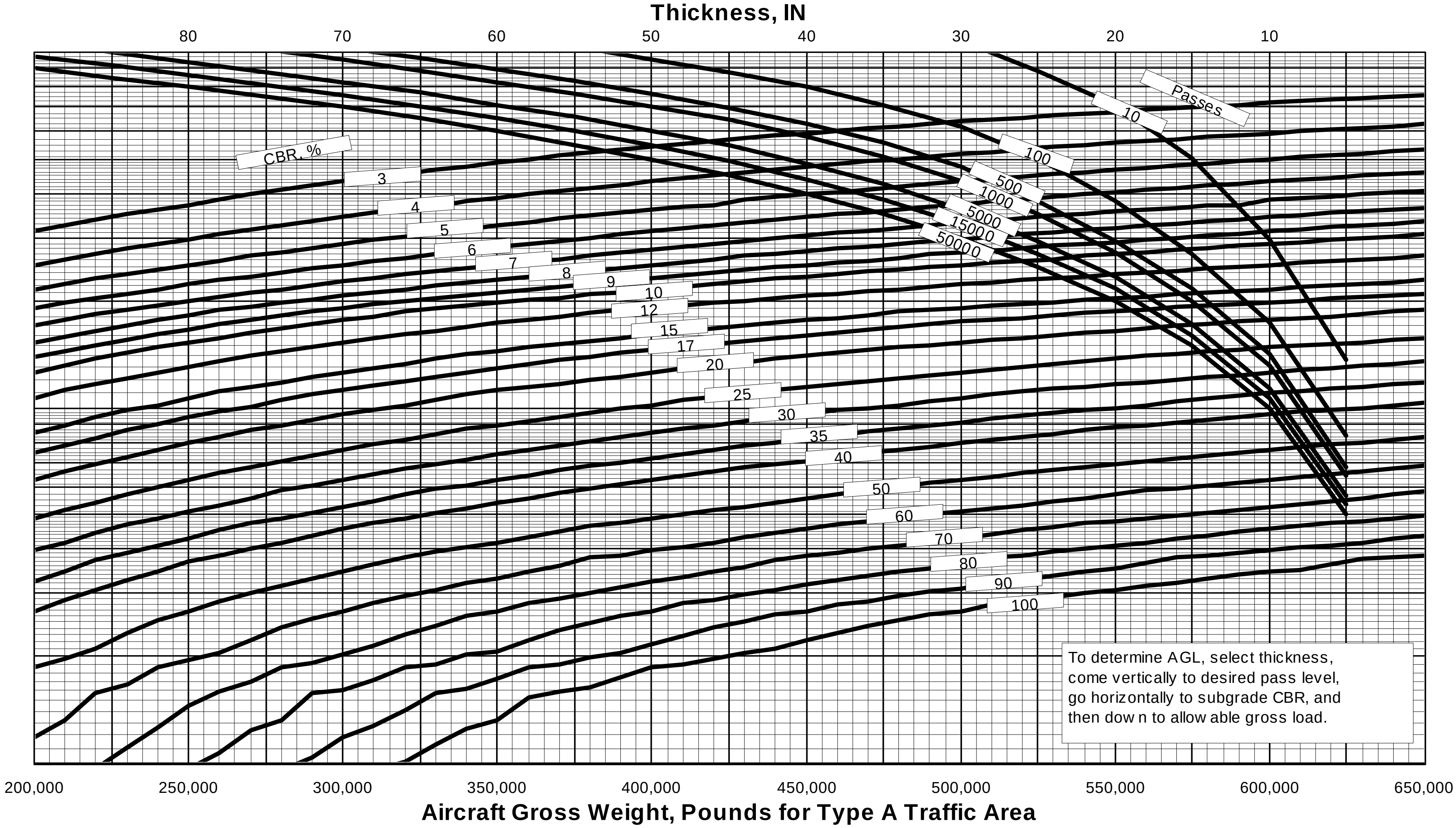


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
F-16C/D

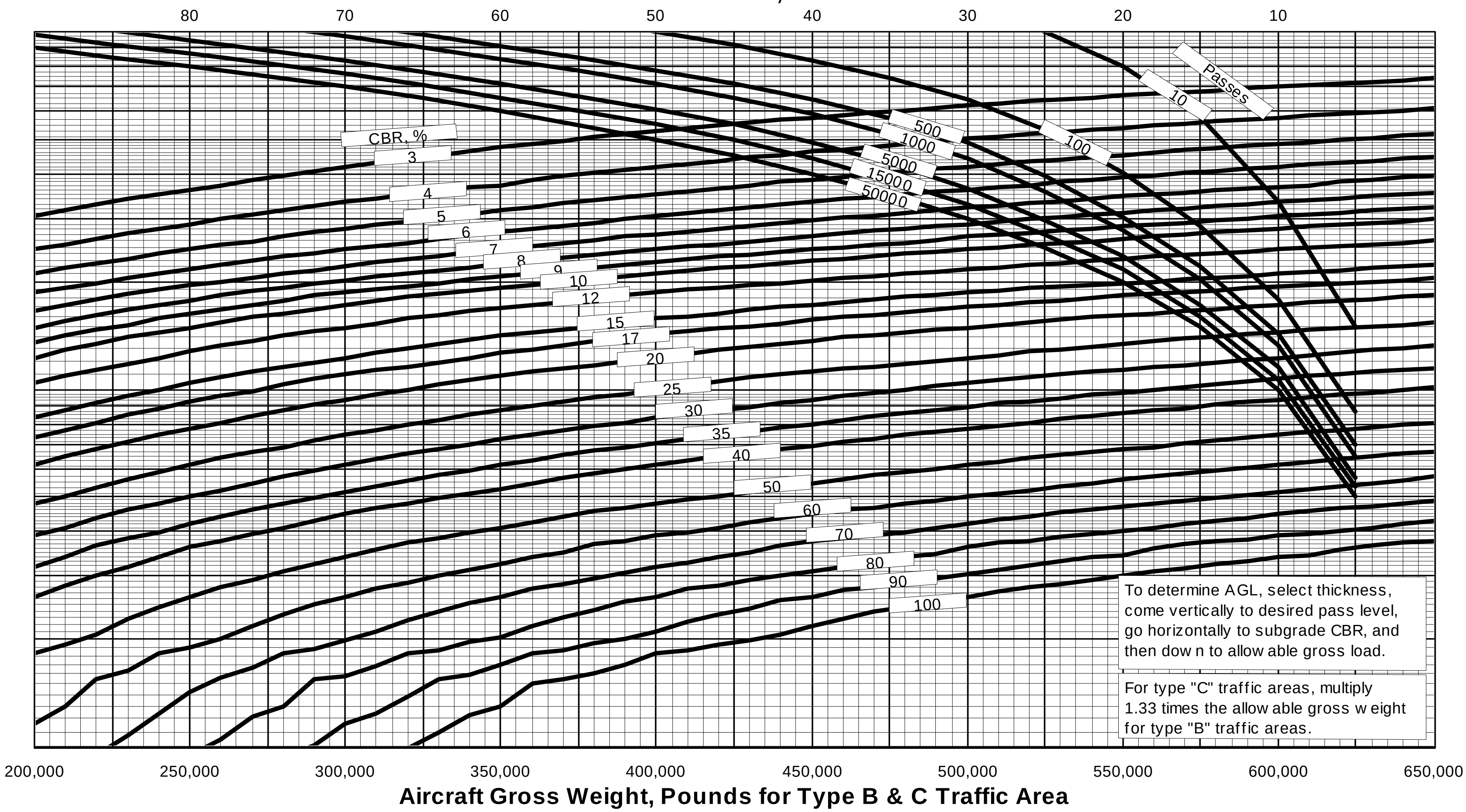


Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area

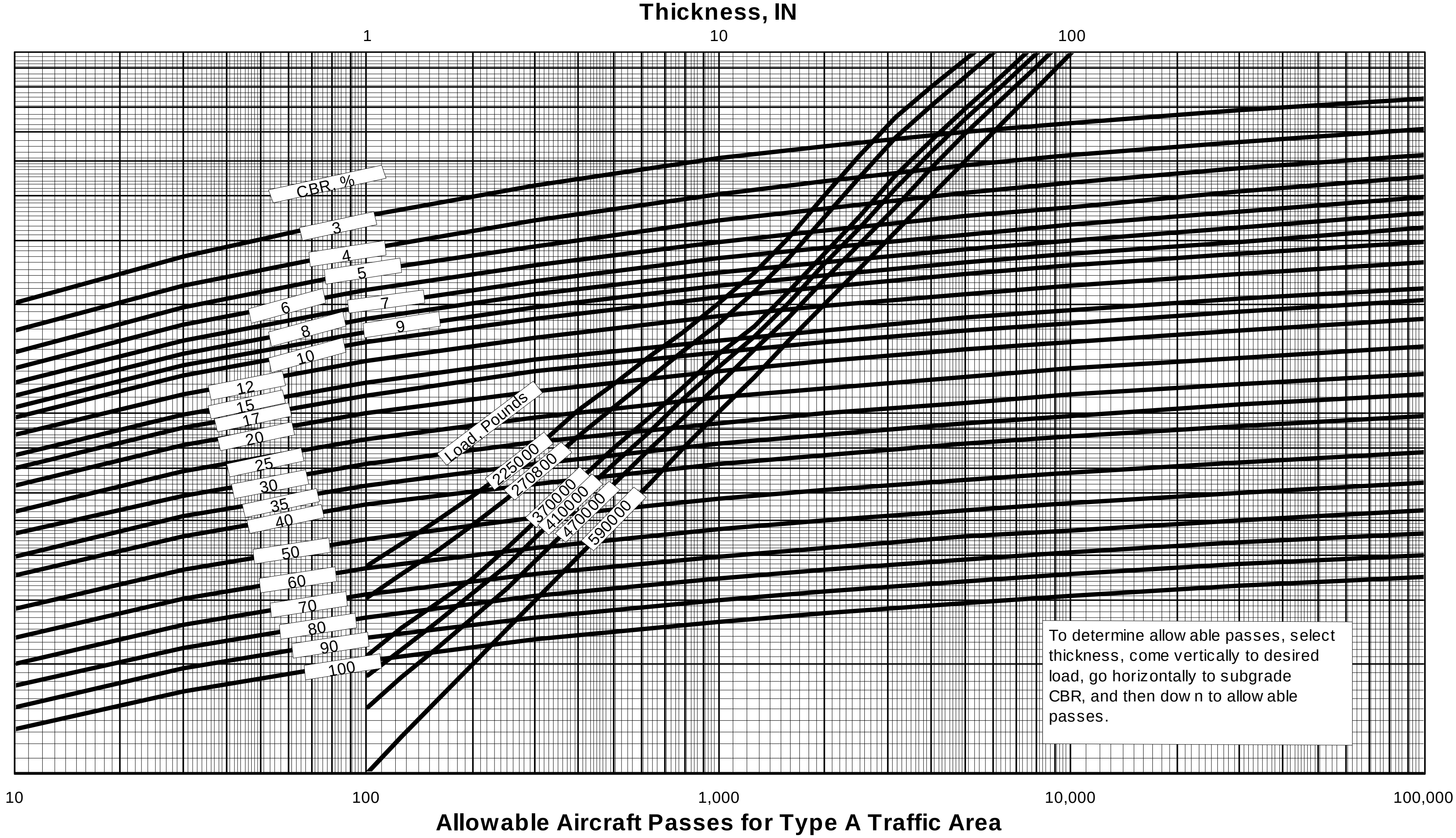
KC-10



Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
KC-10

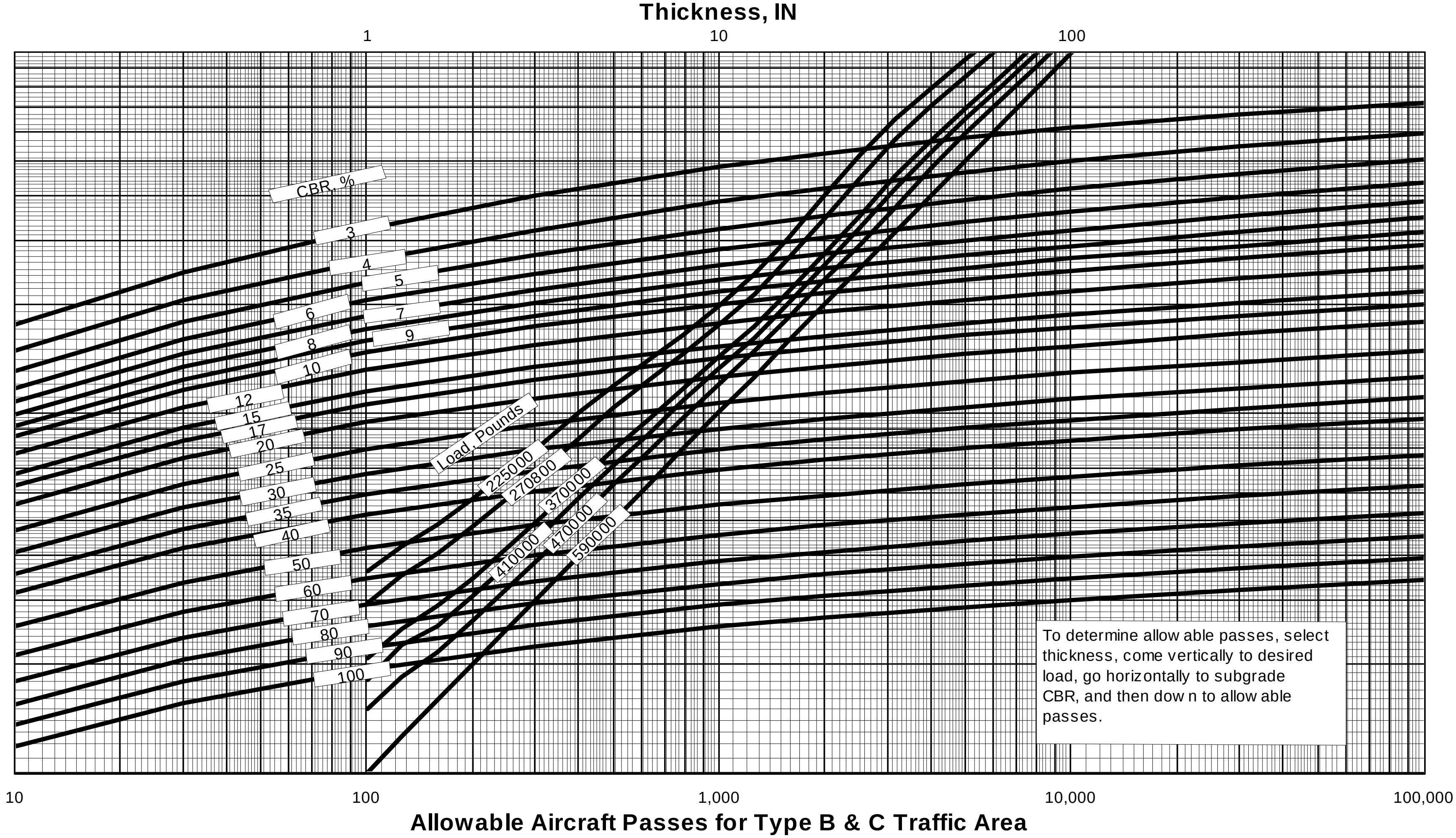


Flexible Pavement Evaluation Allowable Passes - A Traffic Area
KC-10

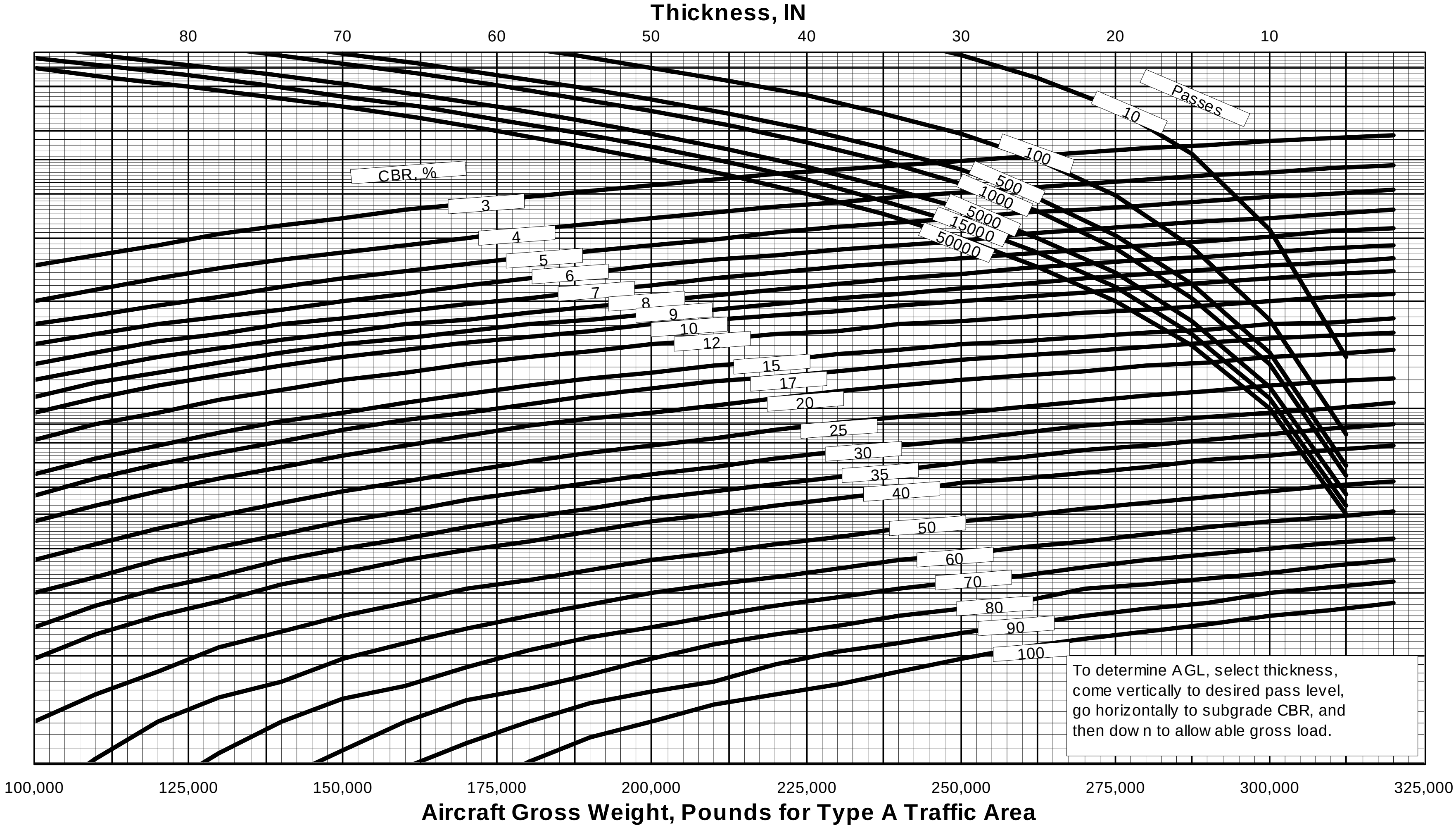


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area

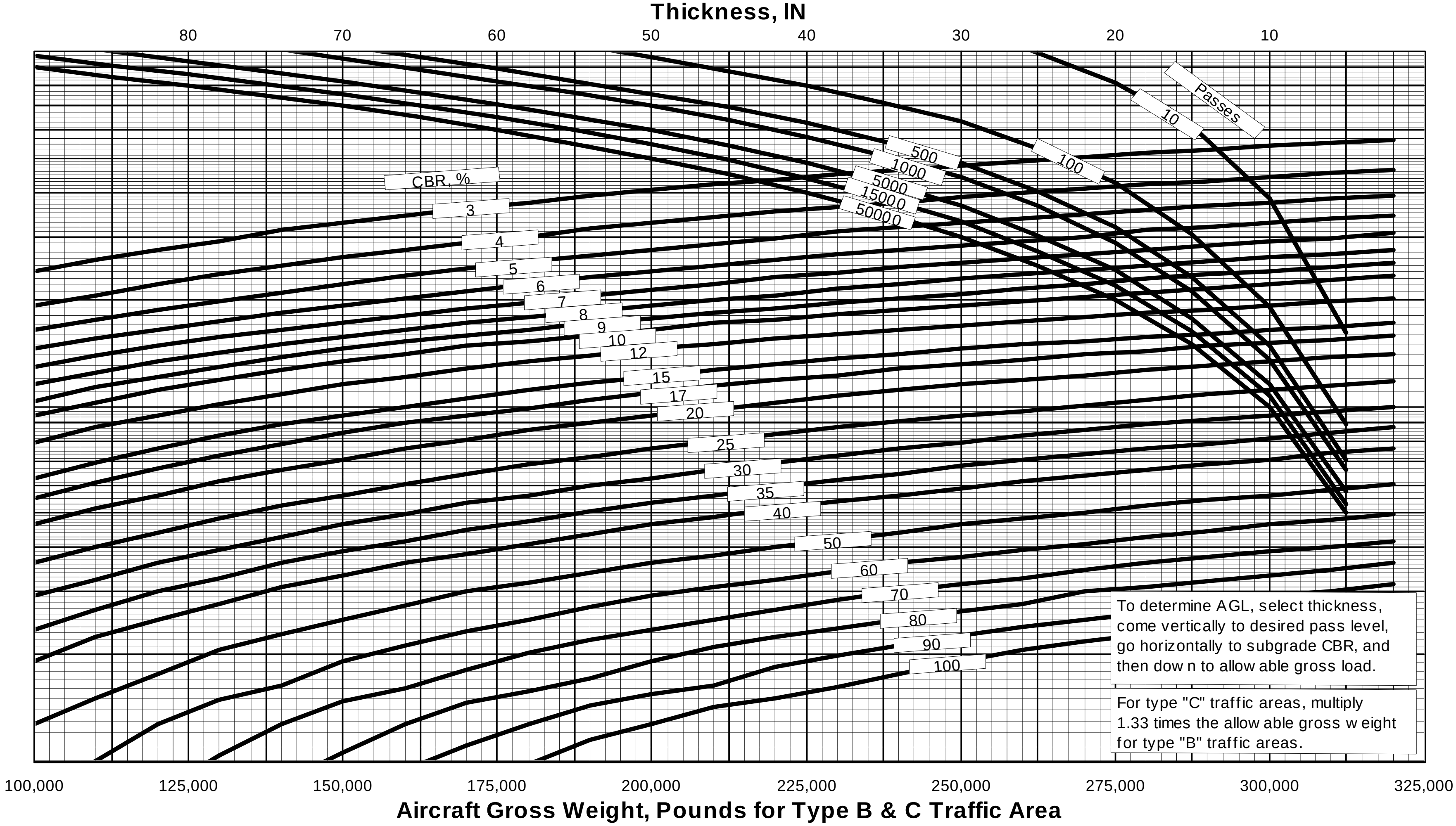
KC-10



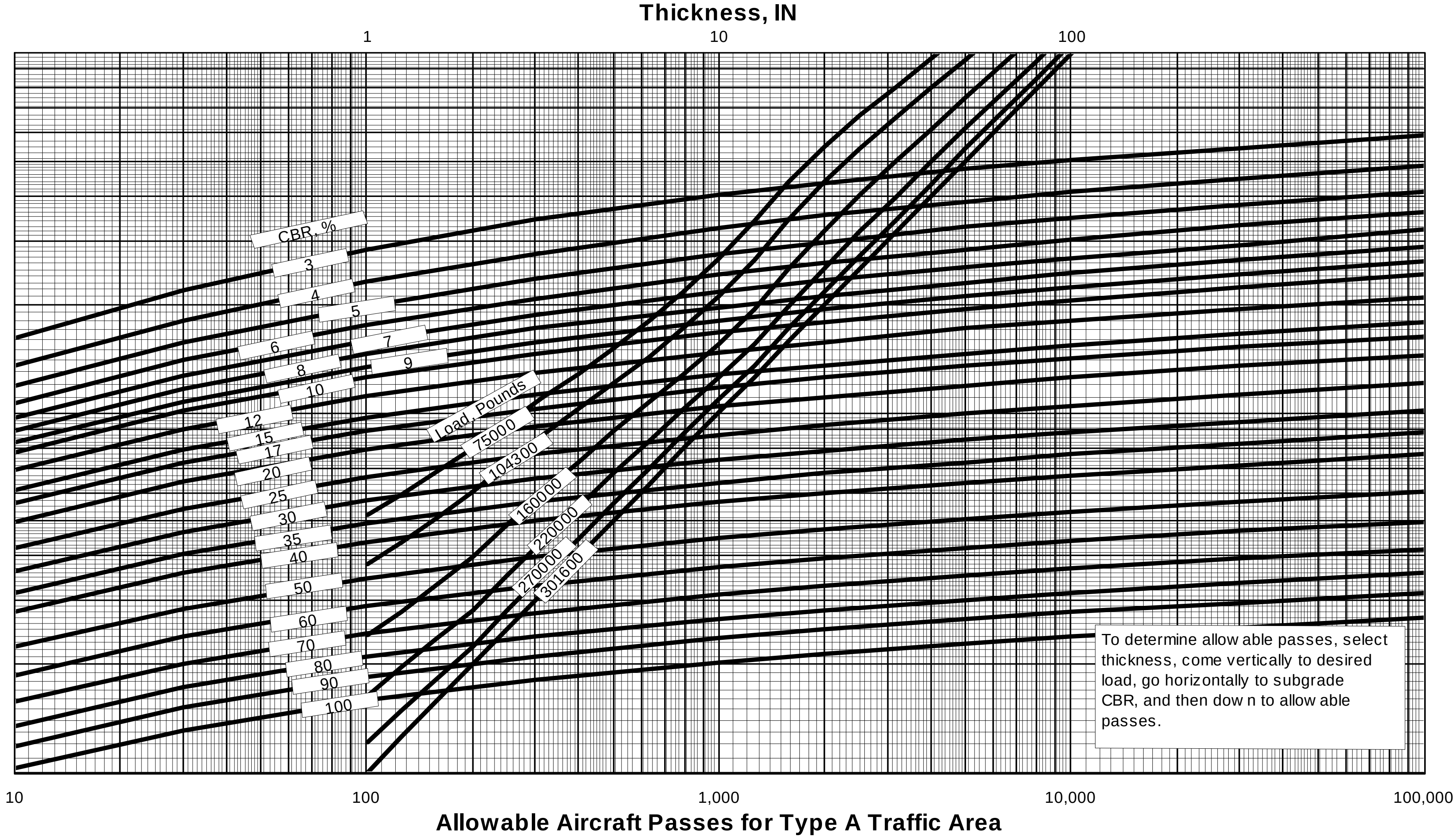
Flexible Pavement Evaluation Allowable Gross Load - A Traffic Area
KC-135



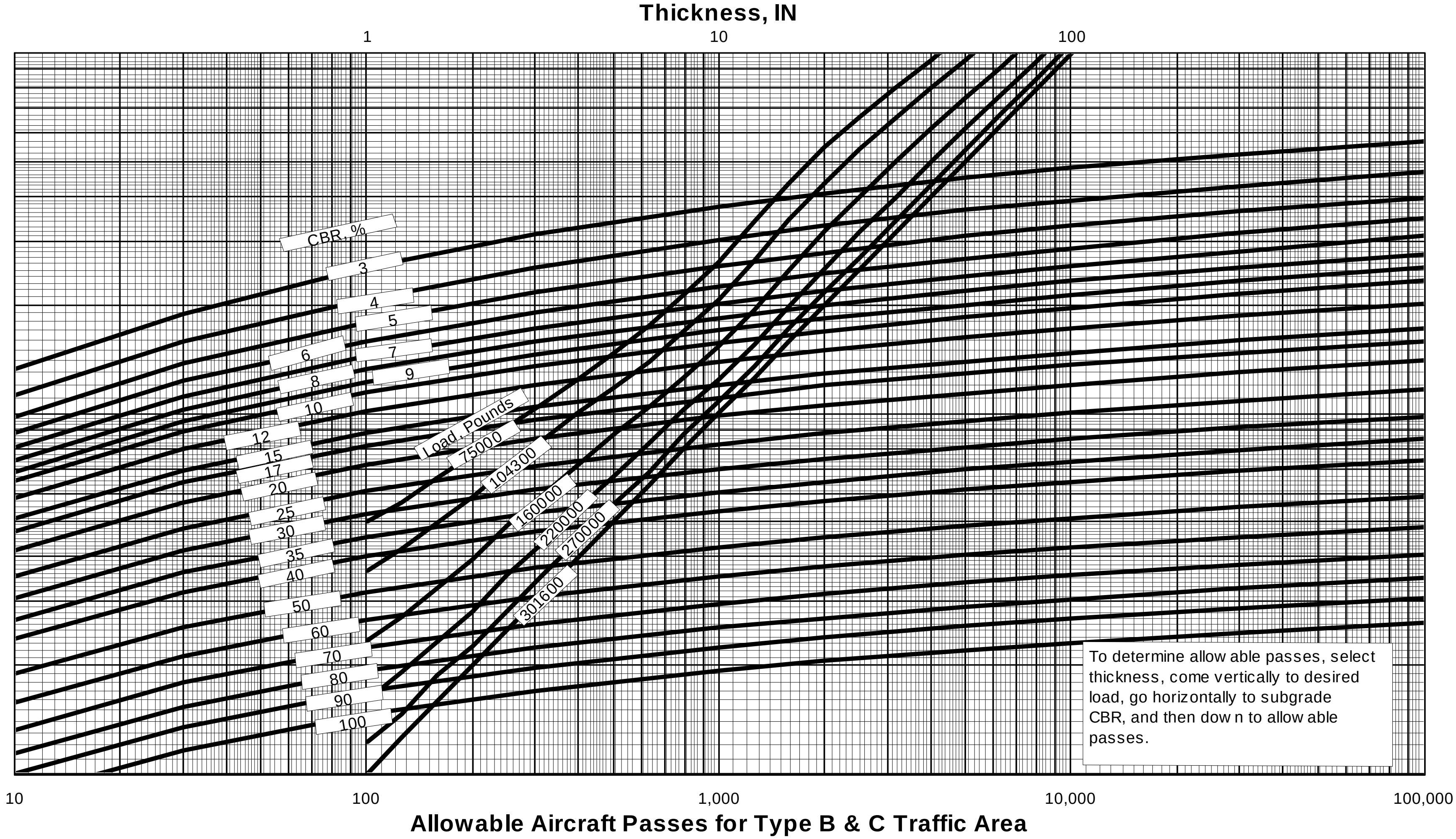
Flexible Pavement Evaluation Allowable Gross Load - B & C Traffic Area
KC-135



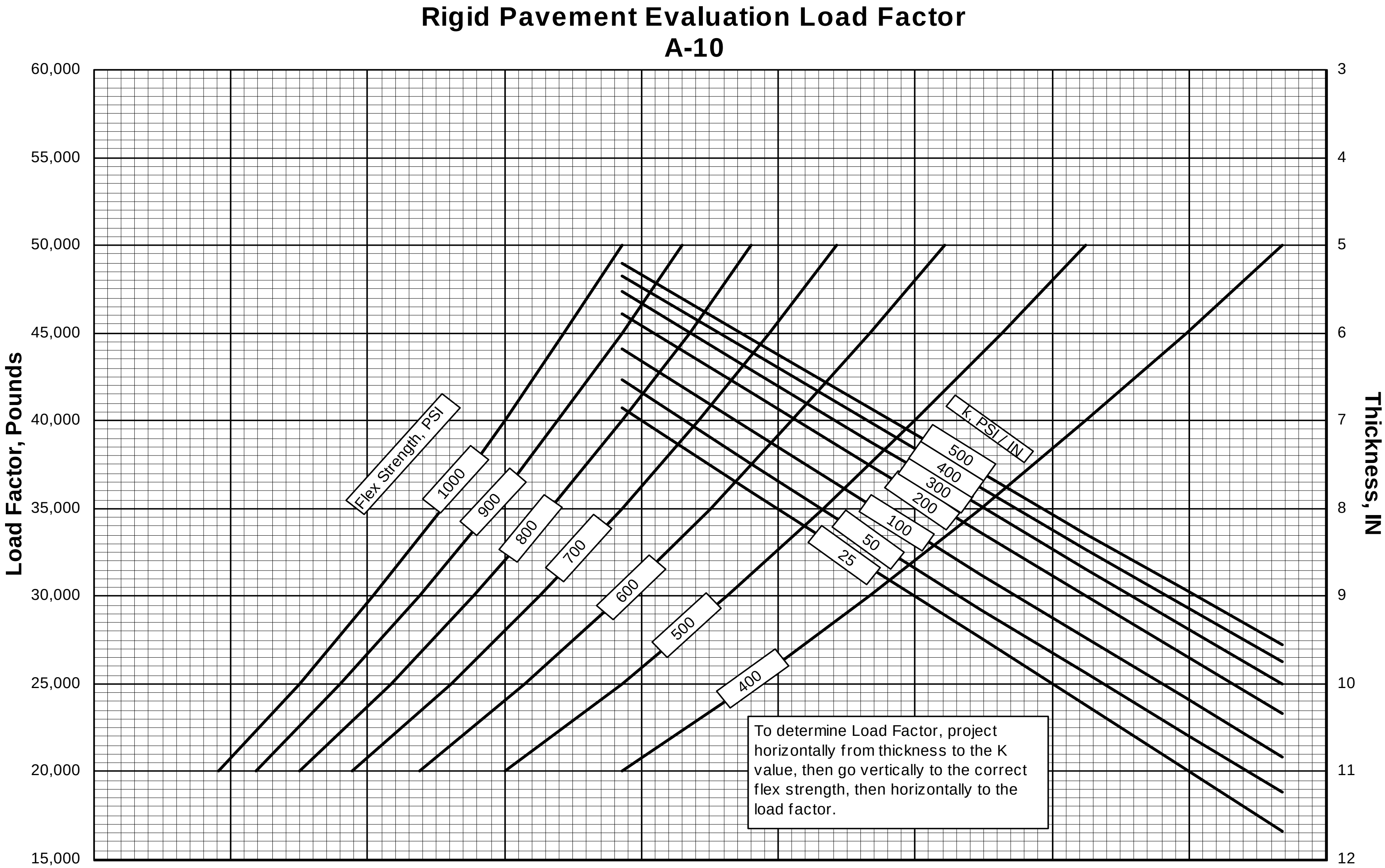
Flexible Pavement Evaluation Allowable Passes - A Traffic Area
KC-135

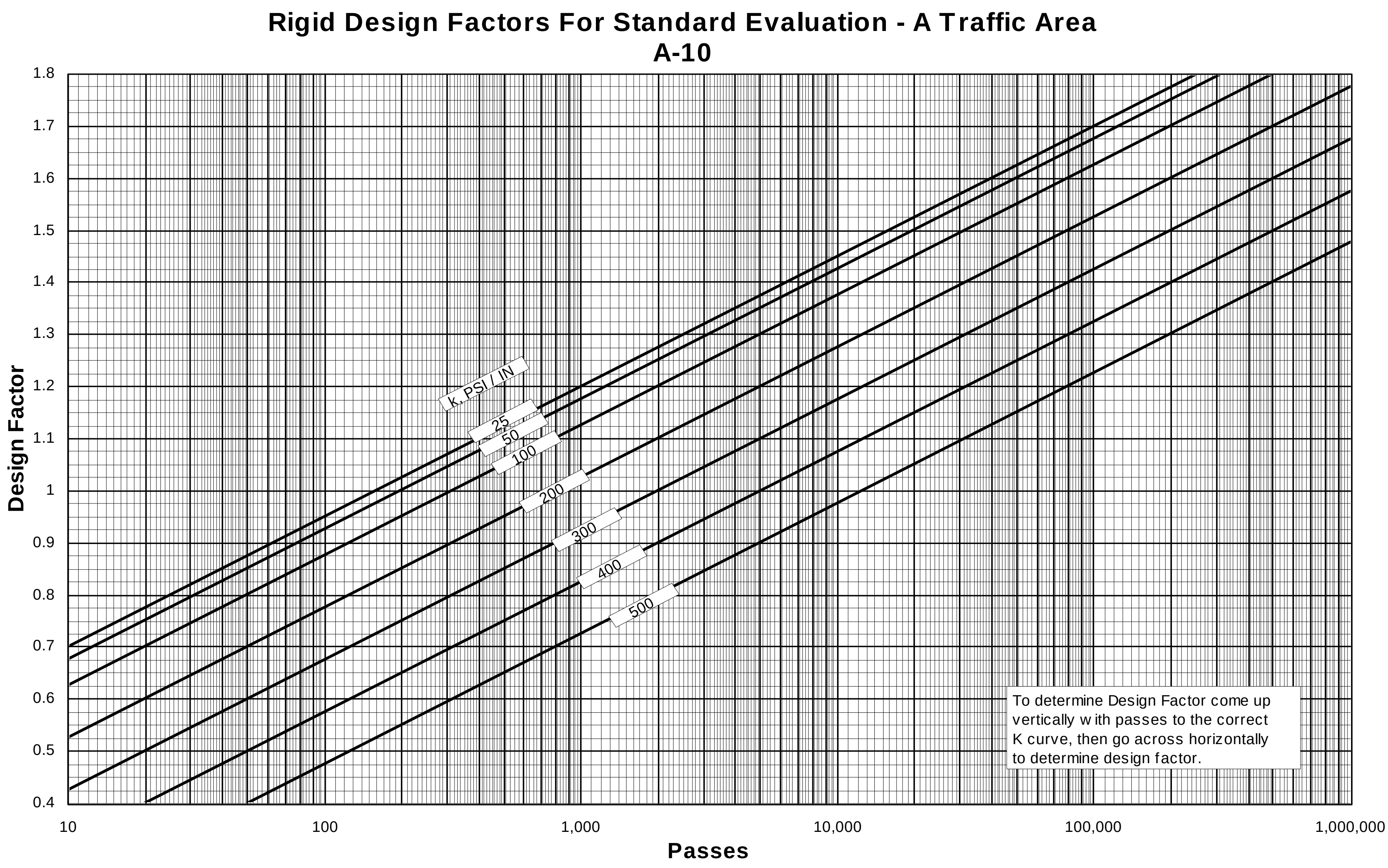


Flexible Pavement Evaluation Allowable Passes - B & C Traffic Area
KC-135

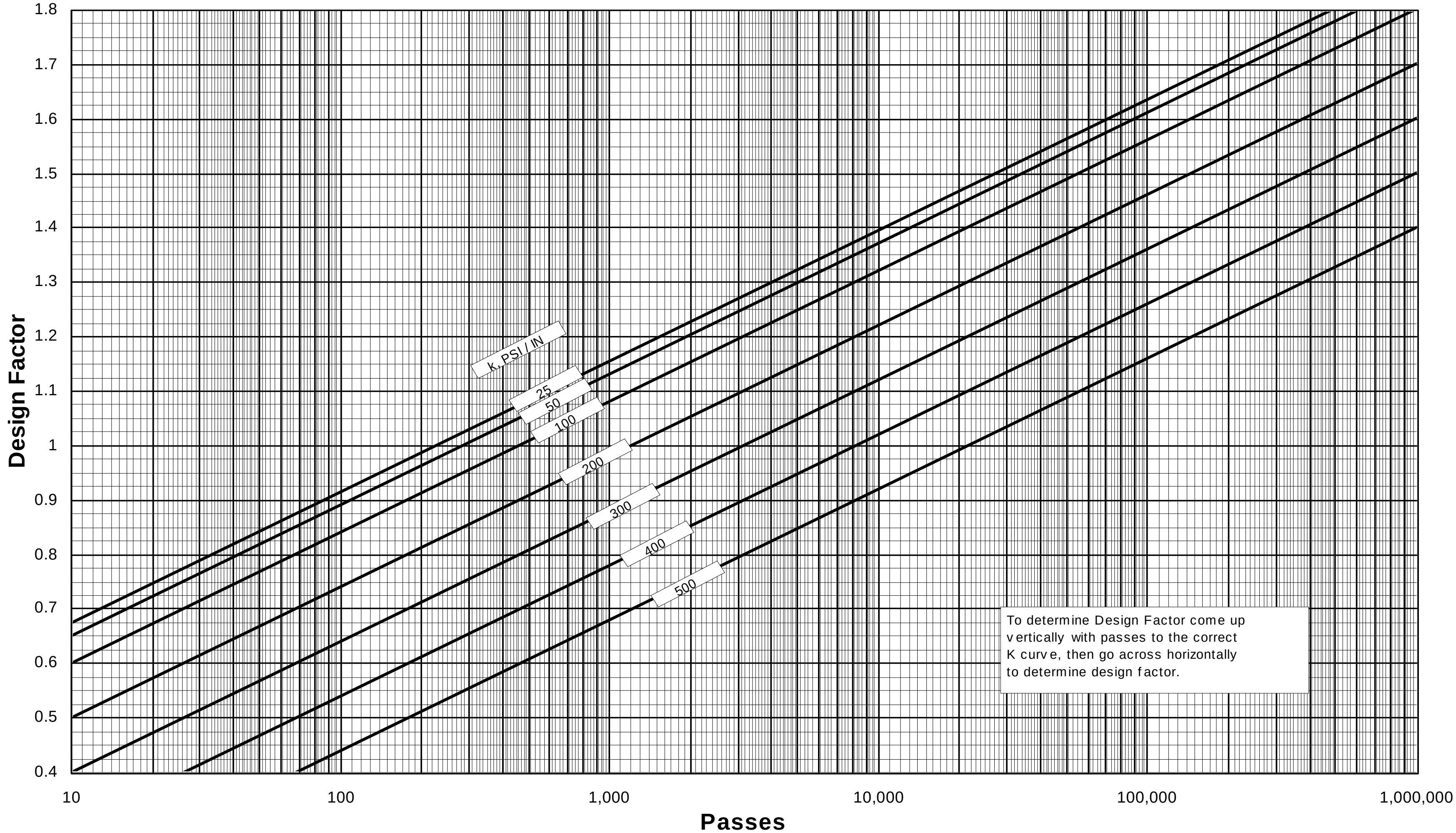


Appendix D: Rigid Pavement Evaluation Curves

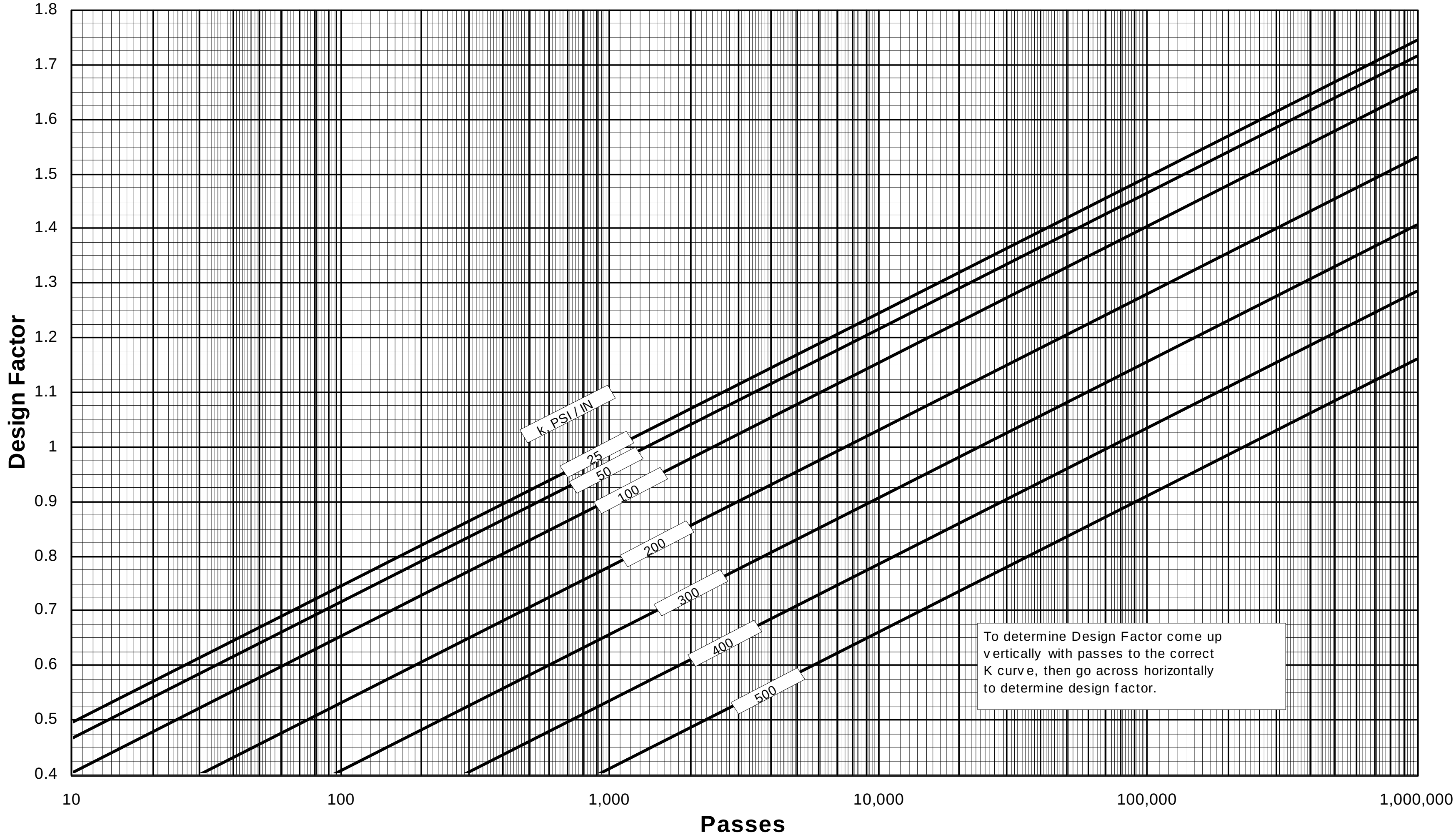



Rigid Design Factors For Standard Evaluation - A Traffic Area
A-10
Design Factor
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000

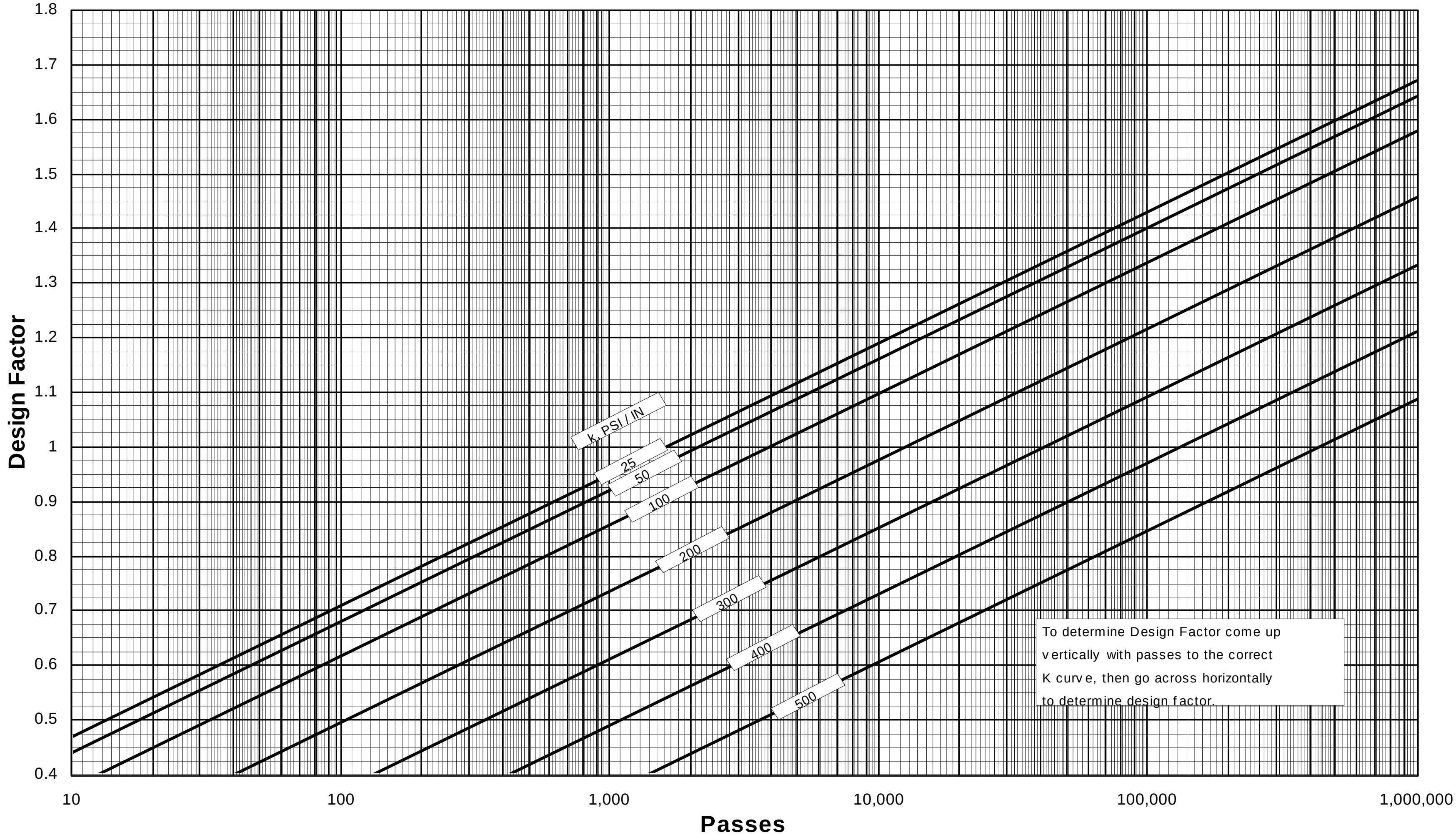
Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
A-10



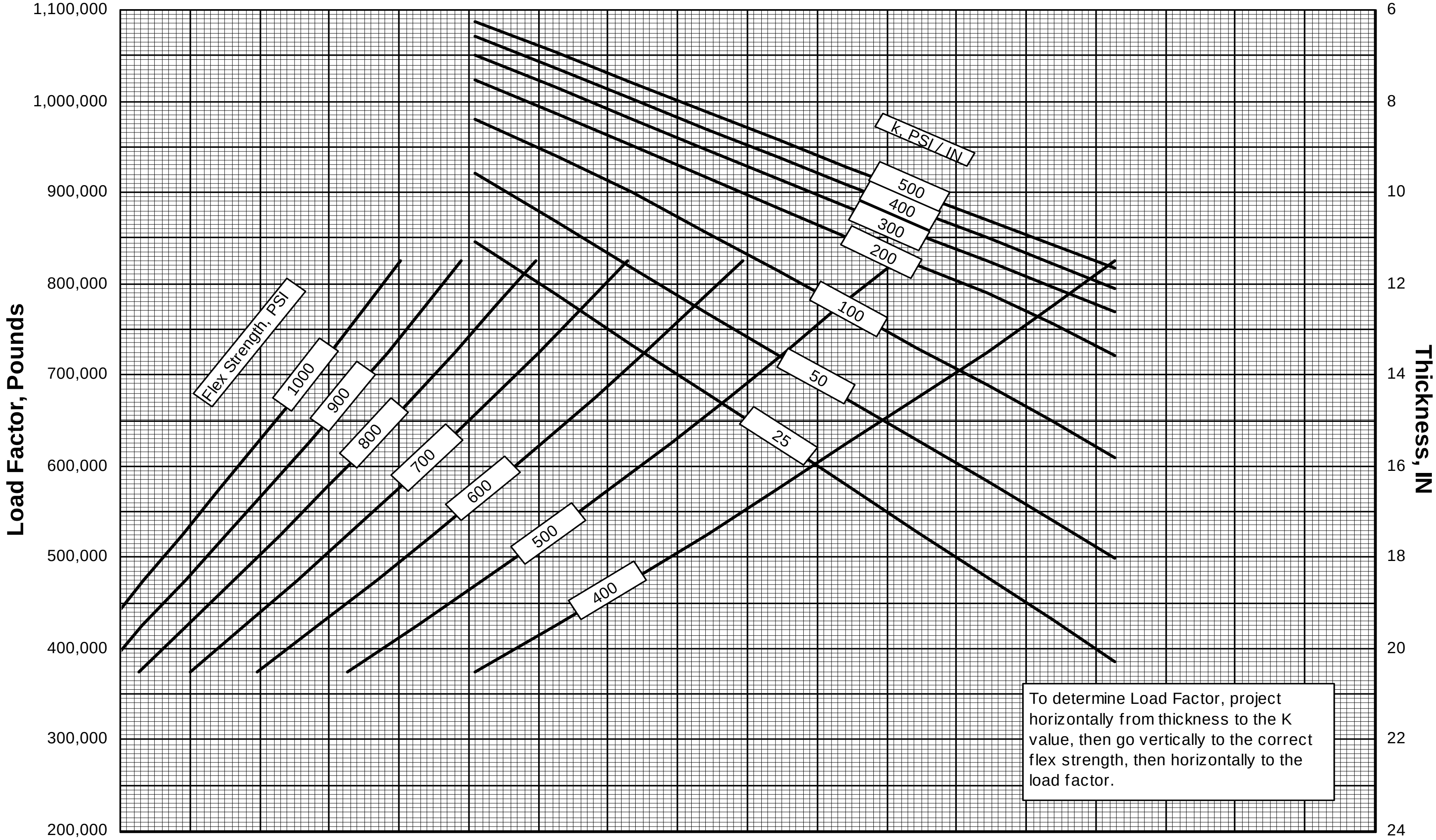
Rigid Design Factors For Extended Evaluation - A Traffic Area
A-10

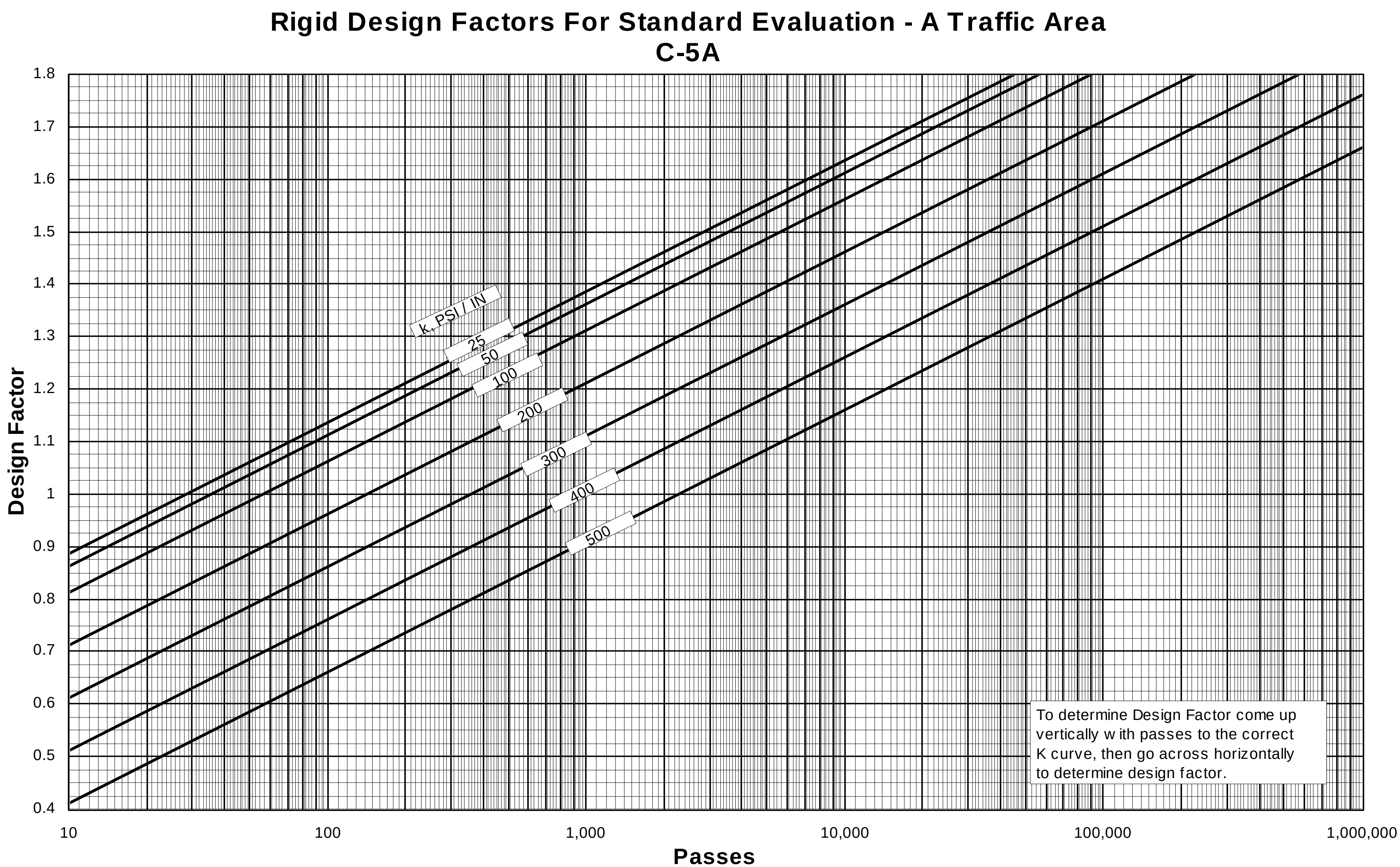


Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
A-10

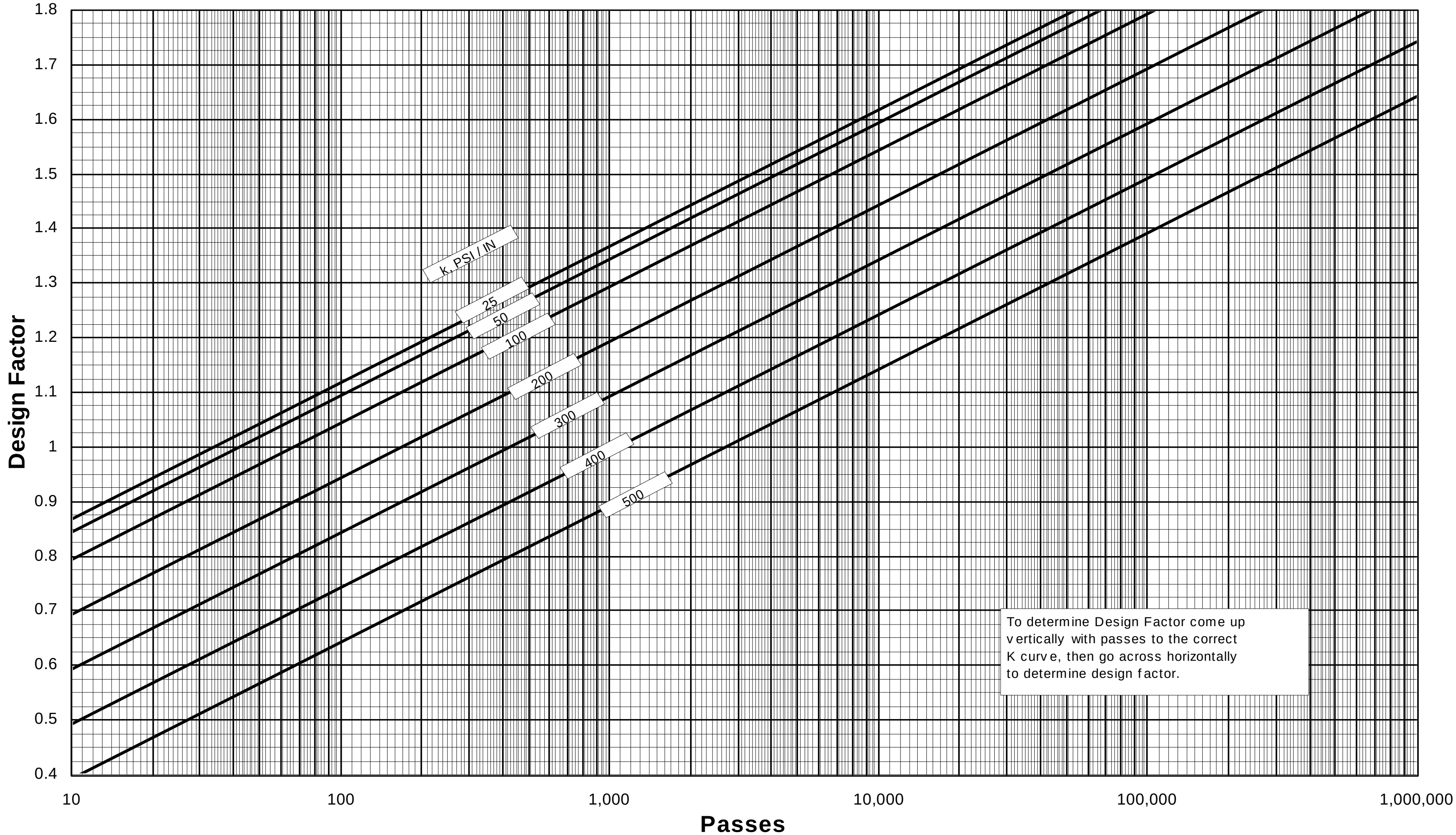


Rigid Pavement Evaluation Load Factor
C-5A

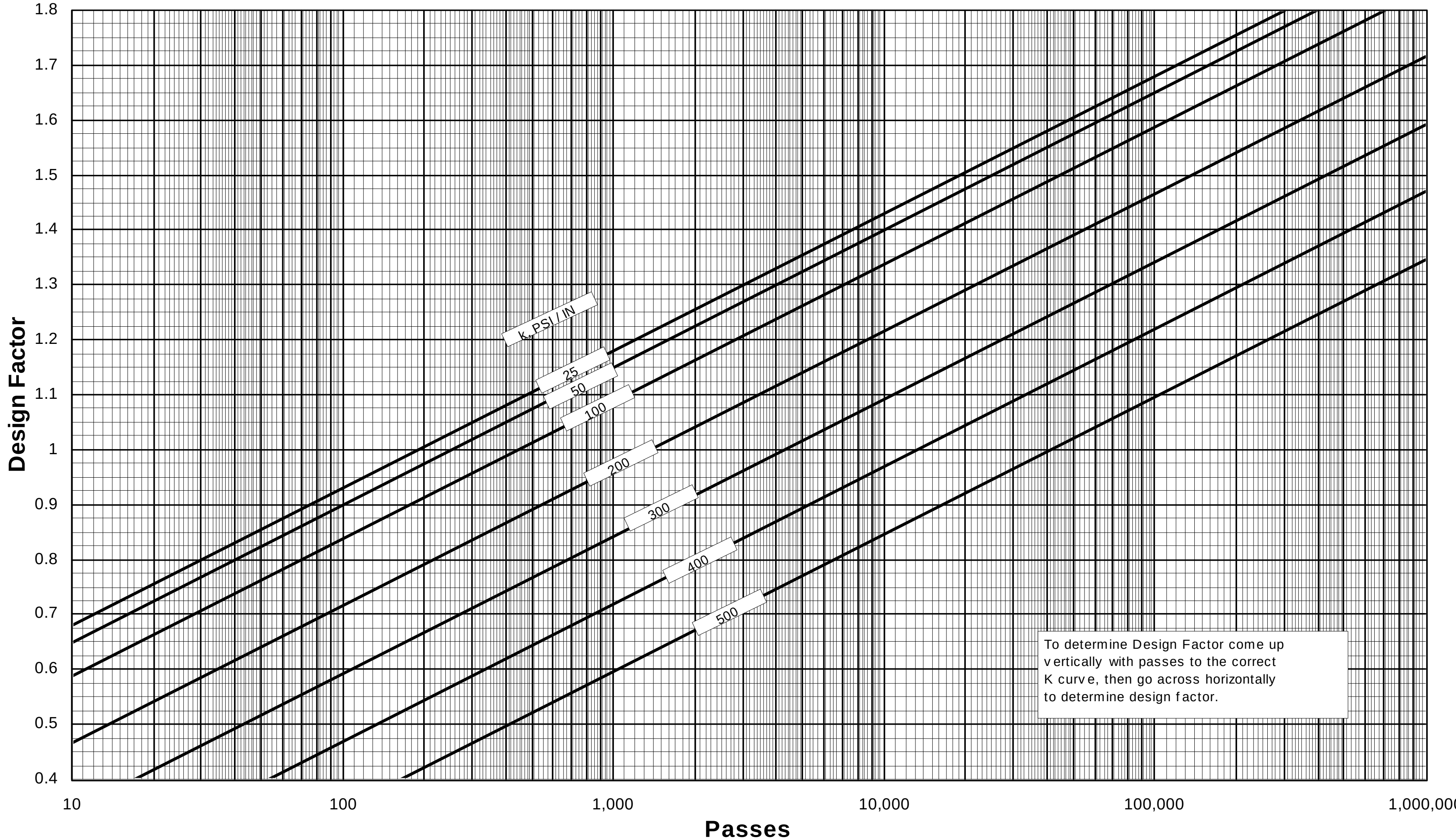


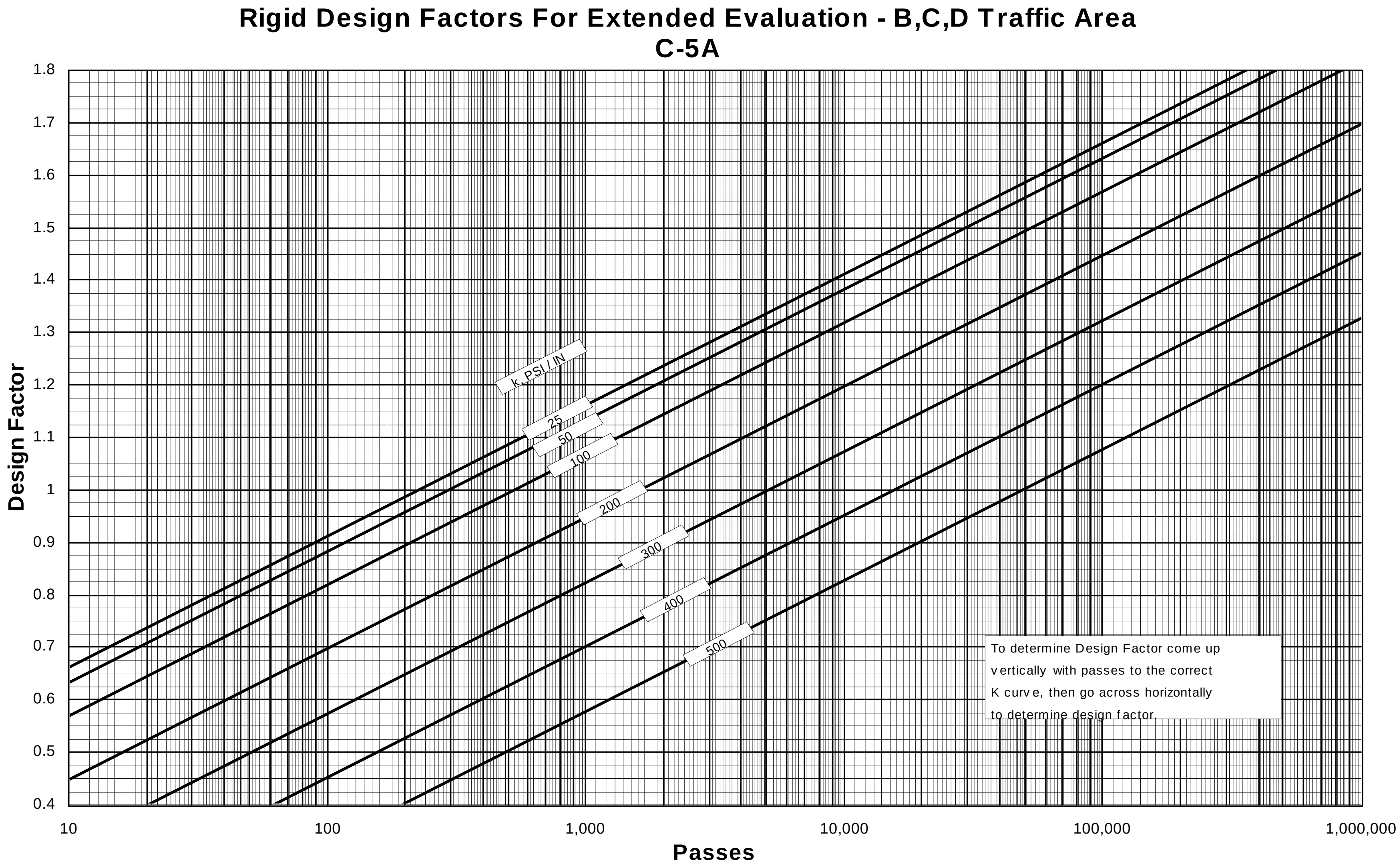

Rigid Design Factors For Standard Evaluation - A Traffic Area
C-5A
Design Factor
Passes
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically w ith passes to the correct K curve, then go across horizontally to determine design factor.

Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
C-5A

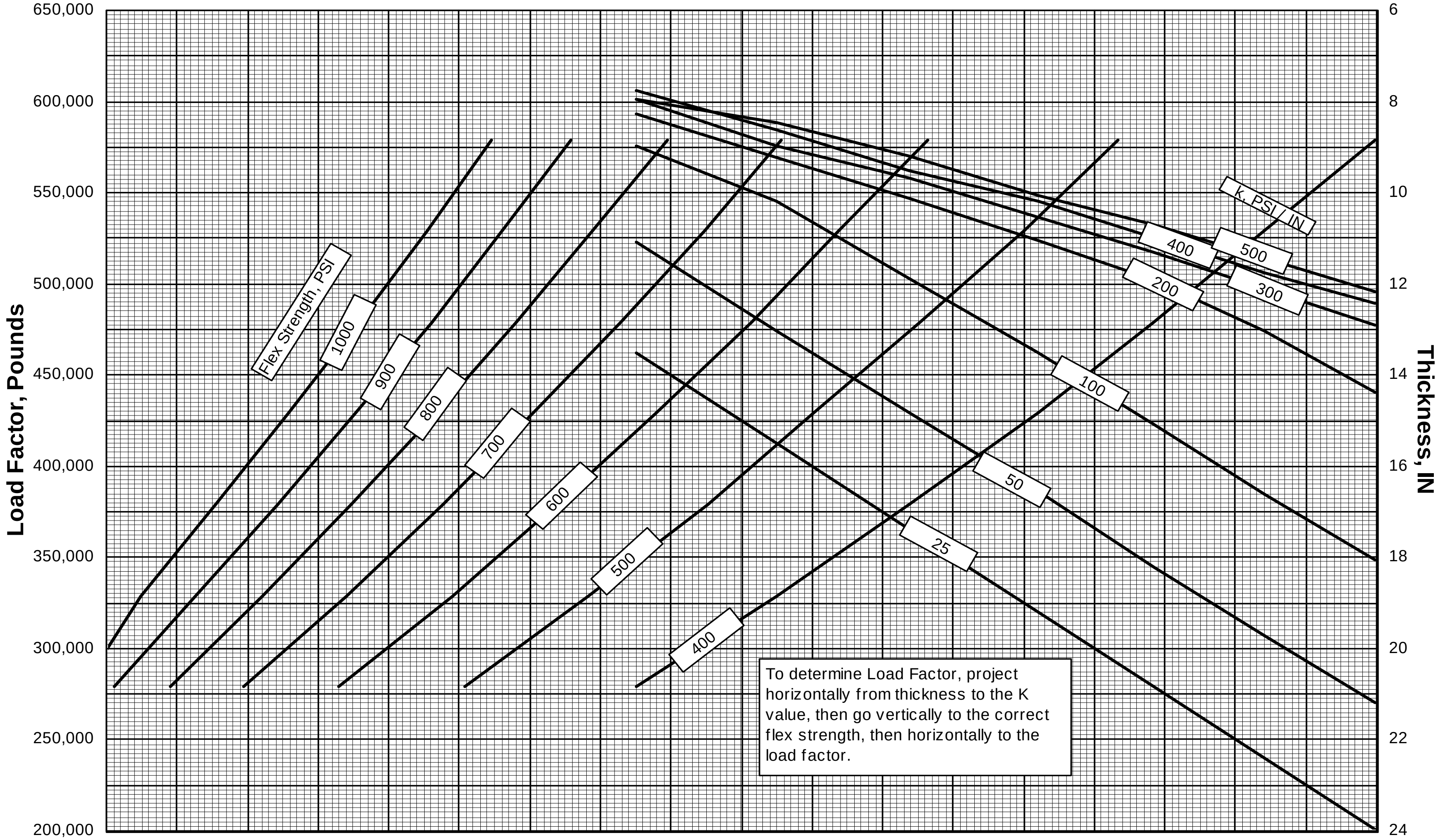


Rigid Design Factors For Extended Evaluation - A Traffic Area
C-5A

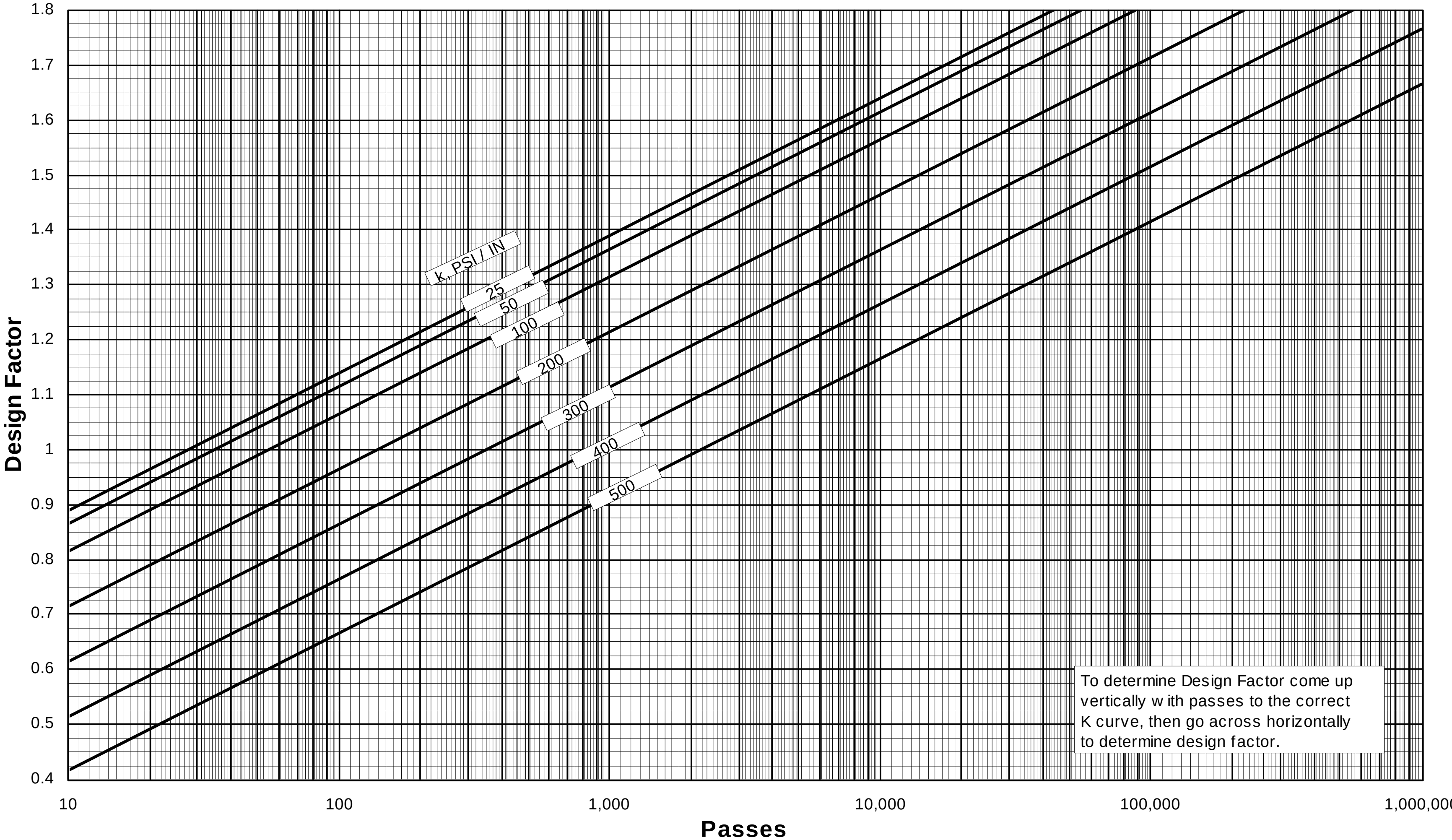



Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
C-5A
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
Passes
10
100
1,000
10,000
100,000
1,000,000
K, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

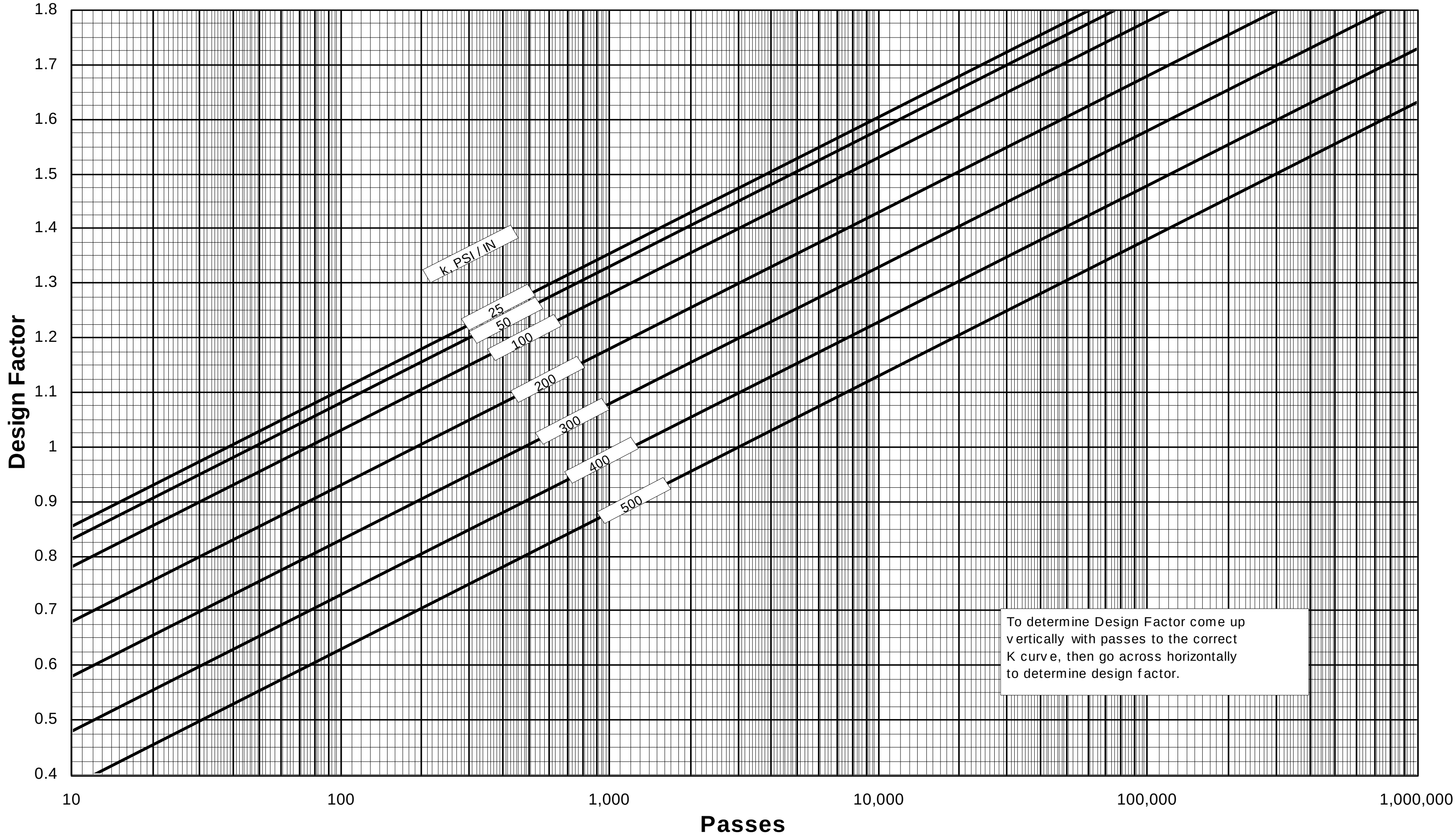
Rigid Pavement Evaluation Load Factor
C-17



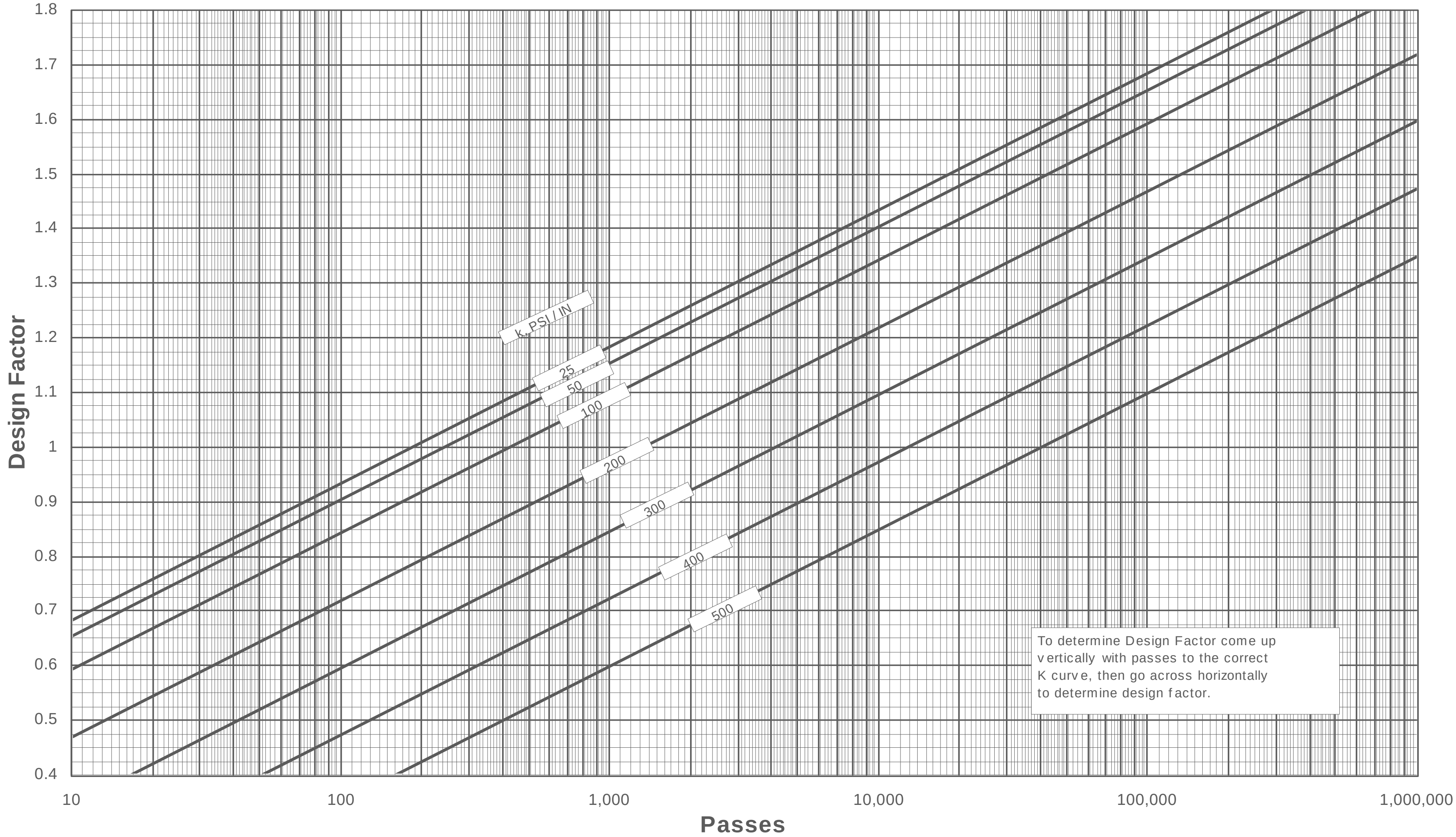
Rigid Design Factors For Standard Evaluation - A Traffic Area
C-17

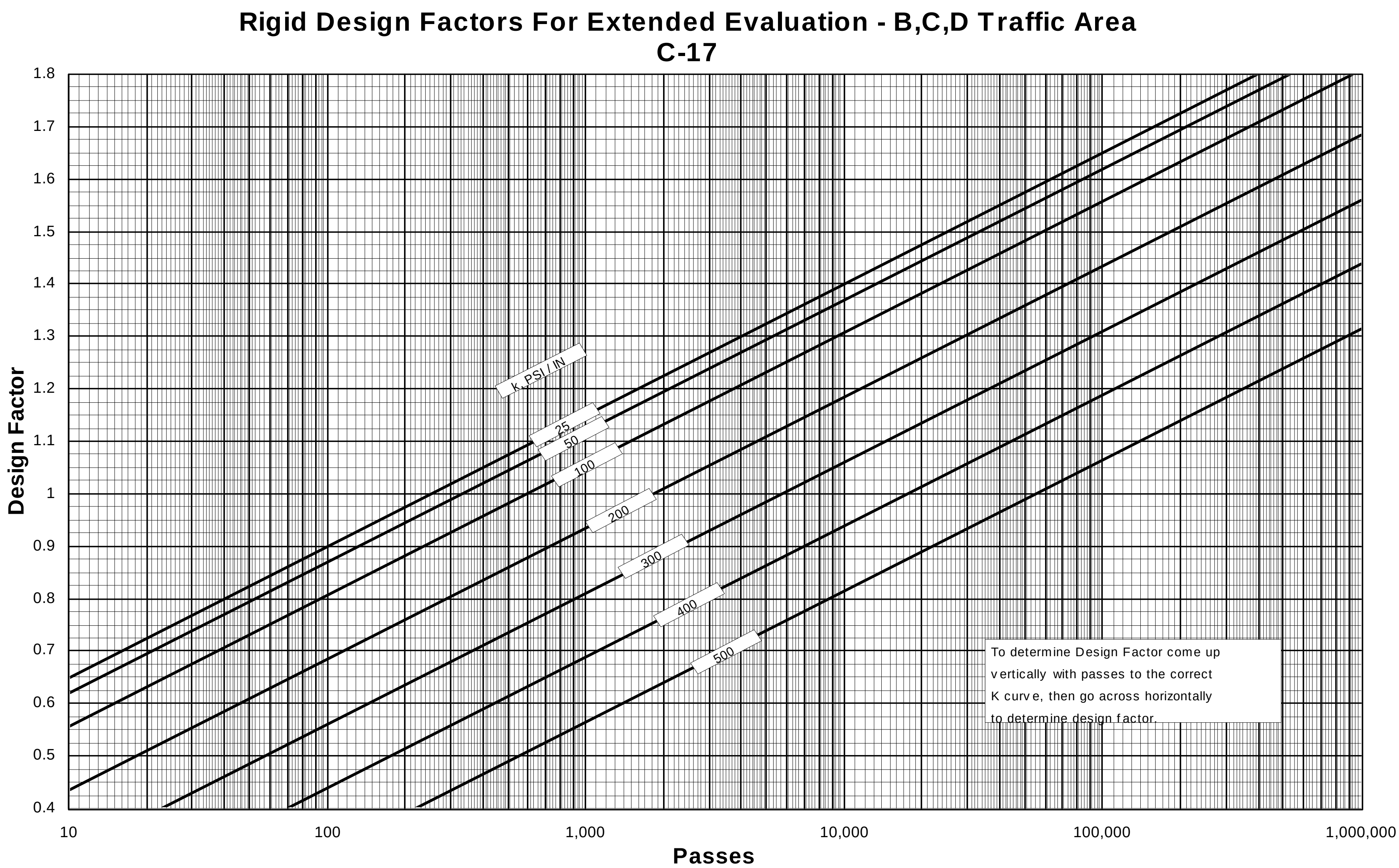


Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
C-17



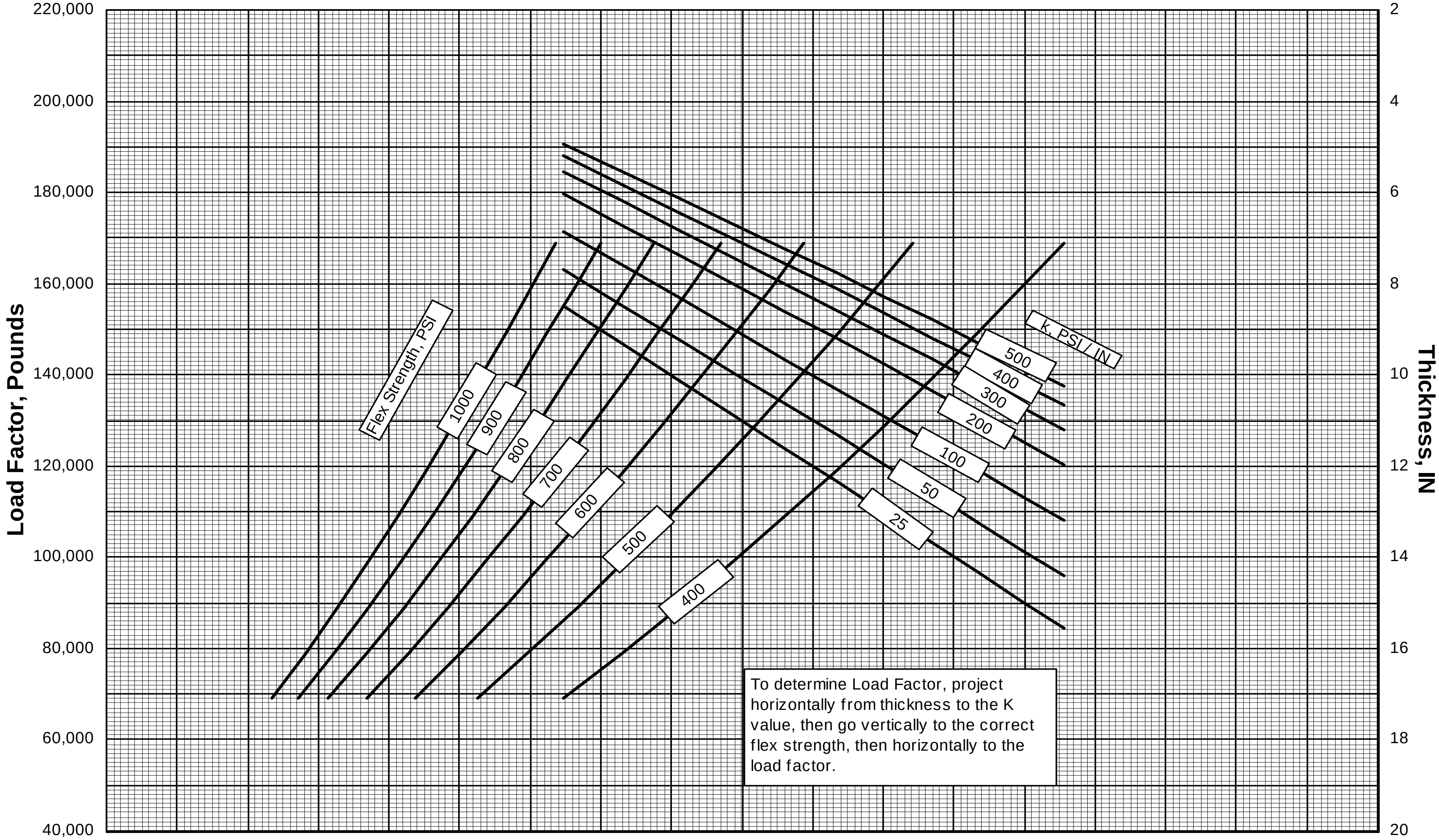
Rigid Design Factors For Extended Evaluation - A Traffic Area
C-17

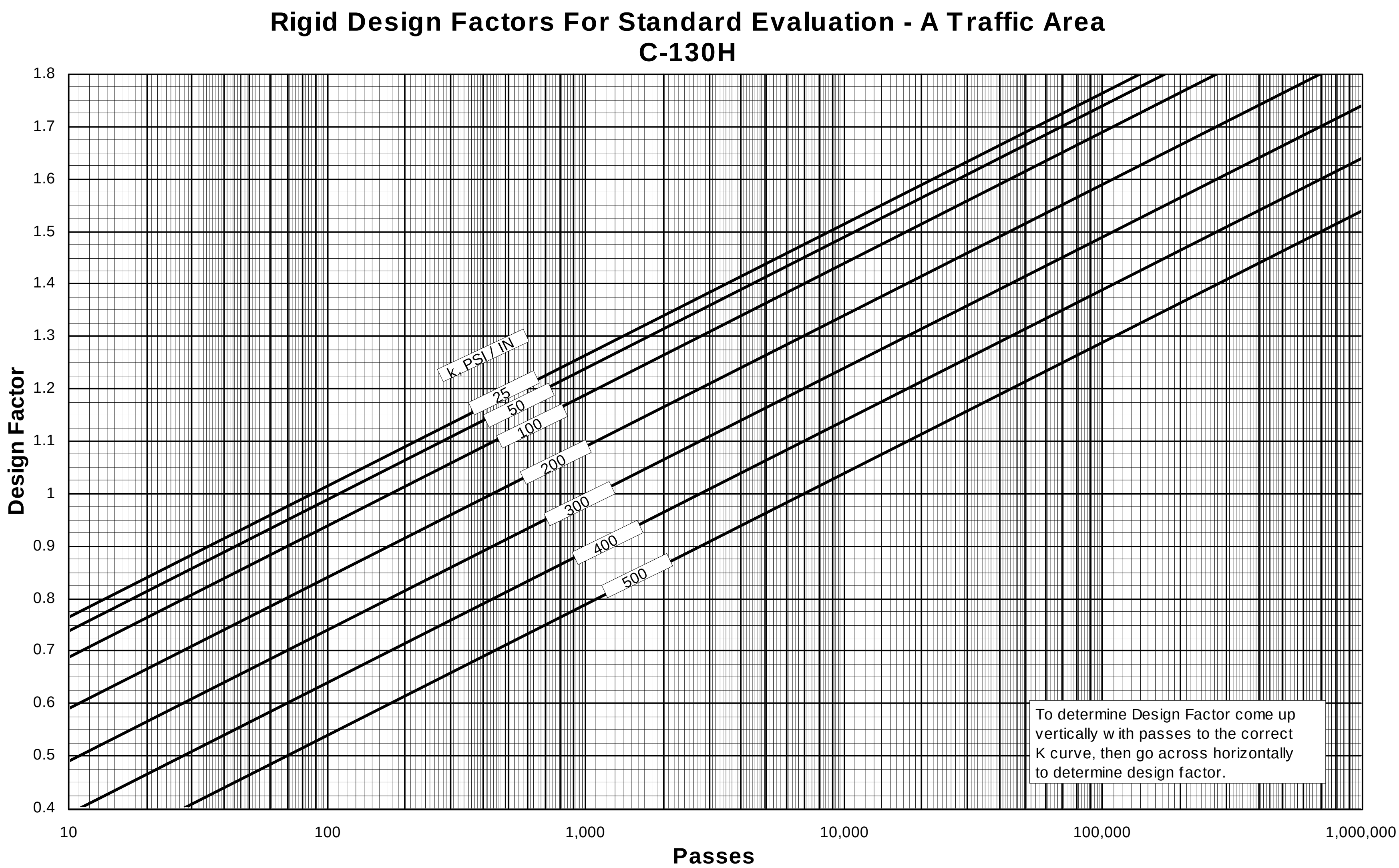




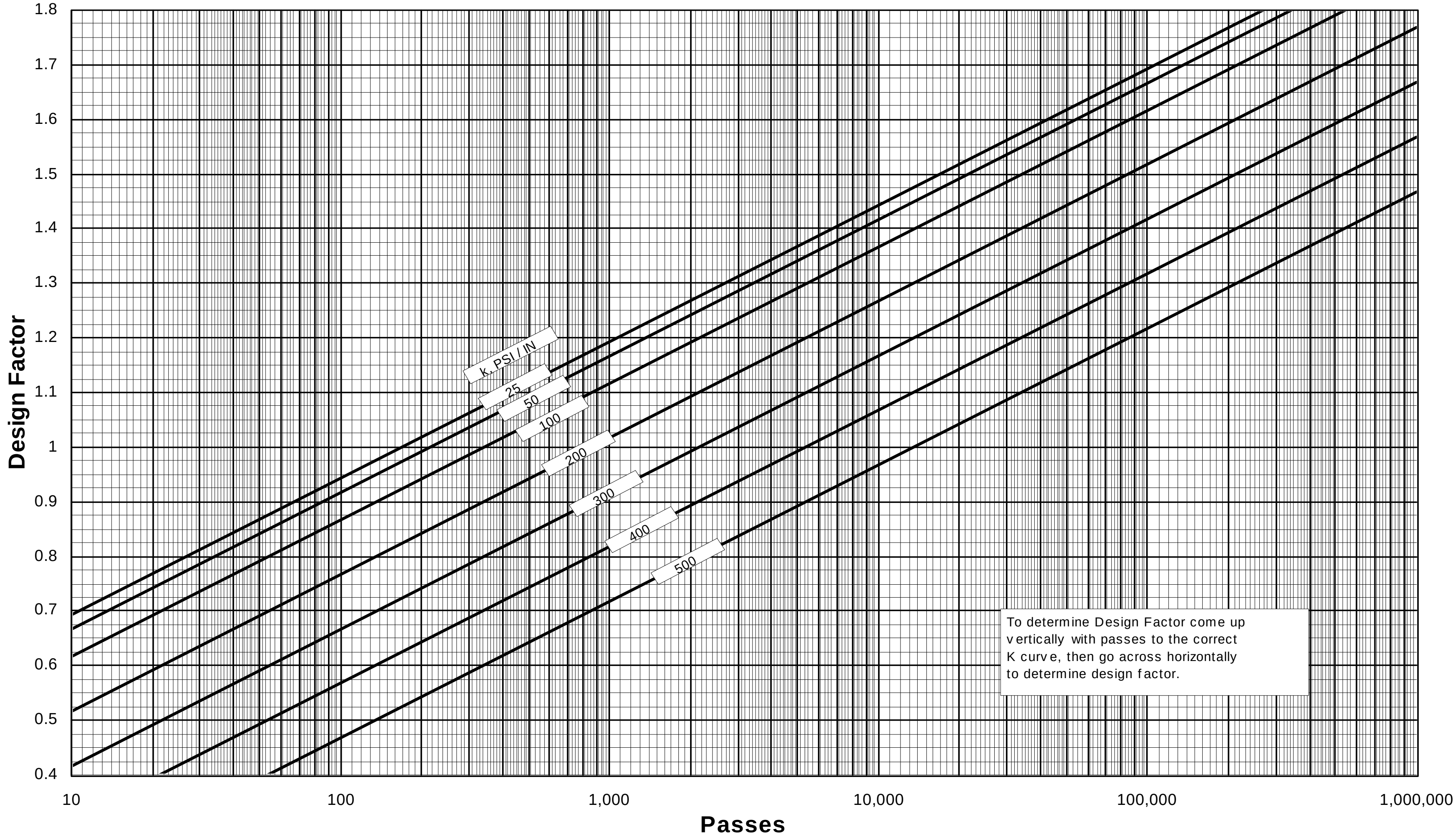
Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
C-17
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
K, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

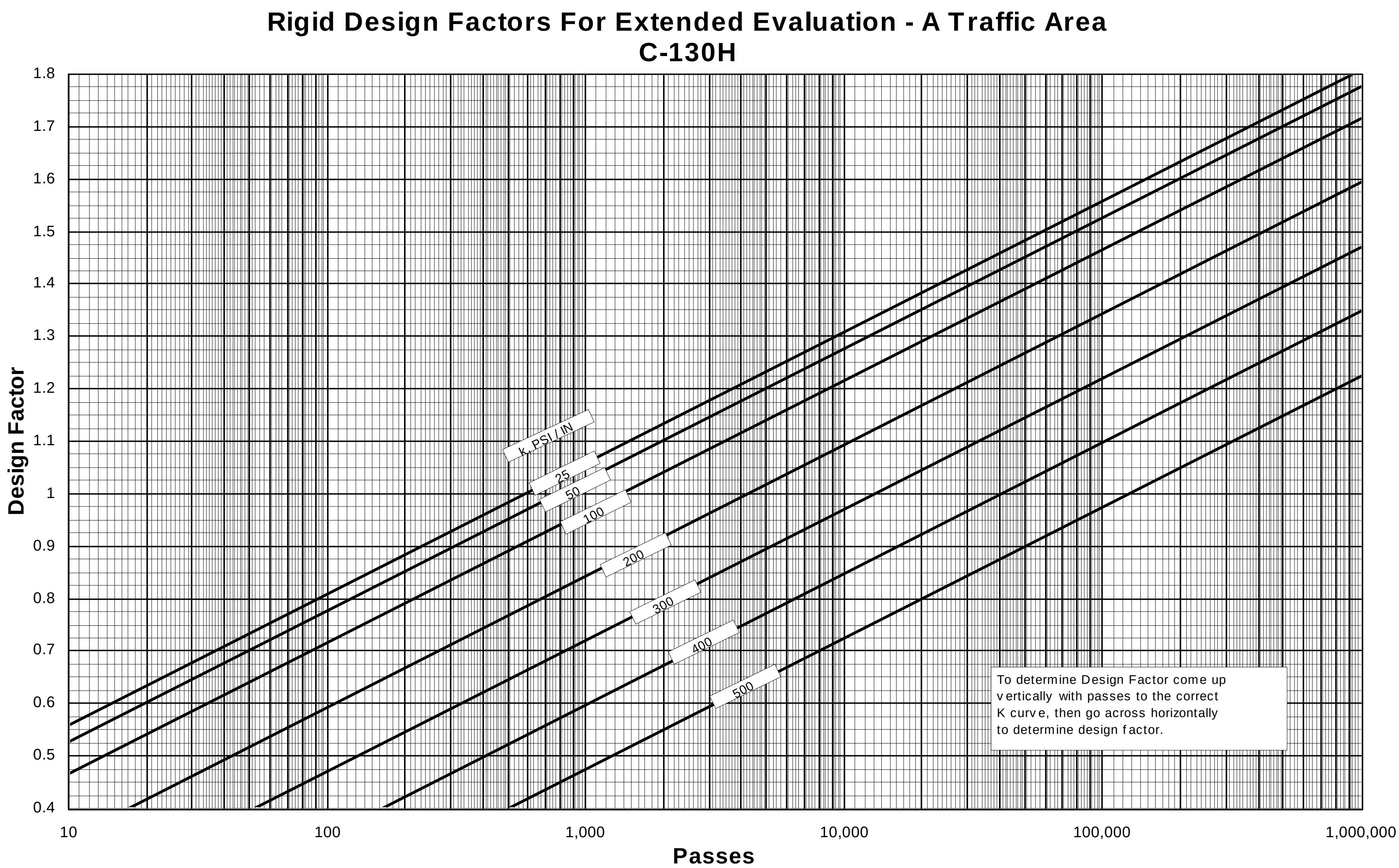
Rigid Pavement Evaluation Load Factor
C-130H




Rigid Design Factors For Standard Evaluation - A Traffic Area
C-130H
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically w ith passes to the correct K curve, then go across horizontally to determine design factor.

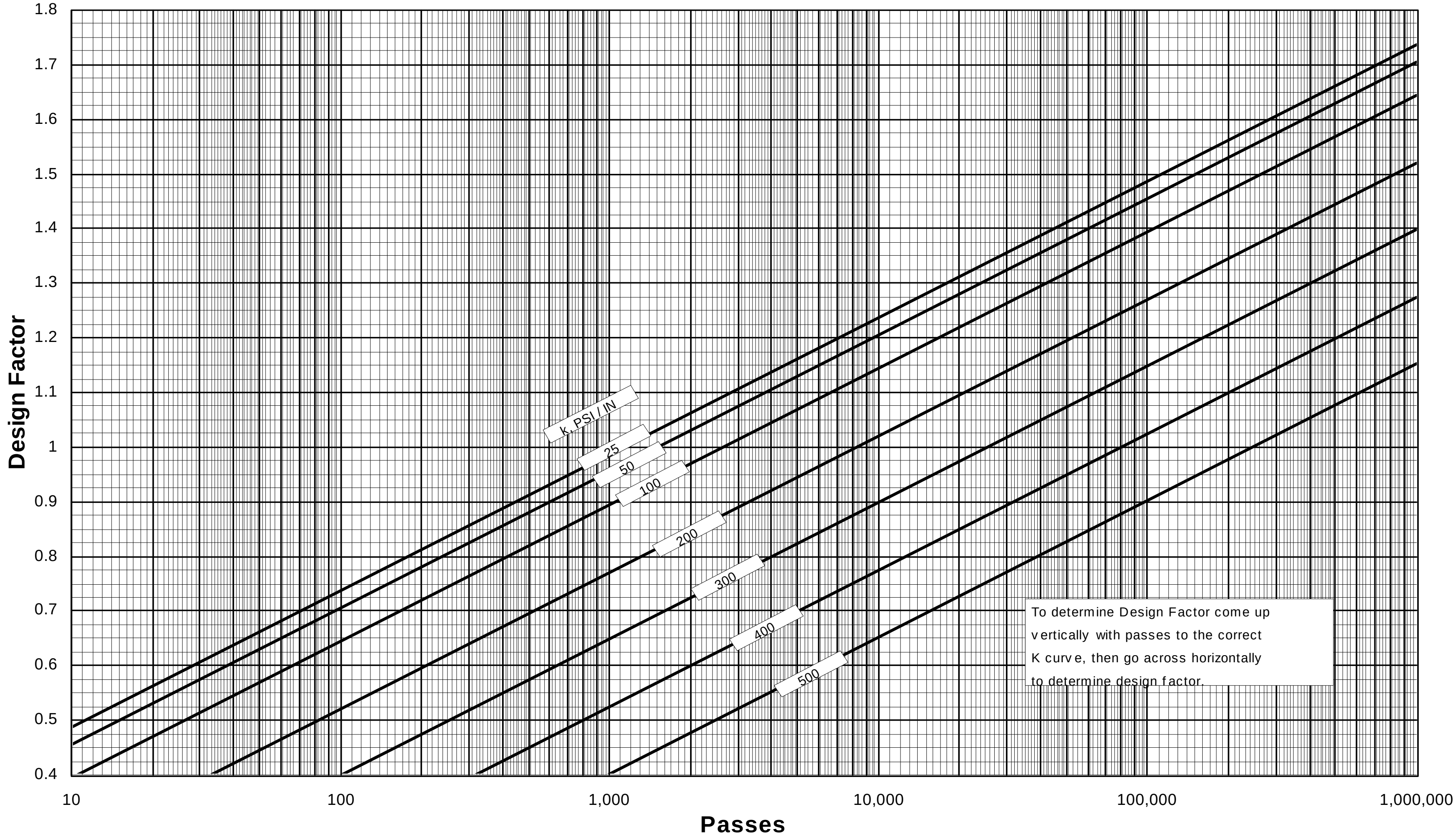
Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
C-130H

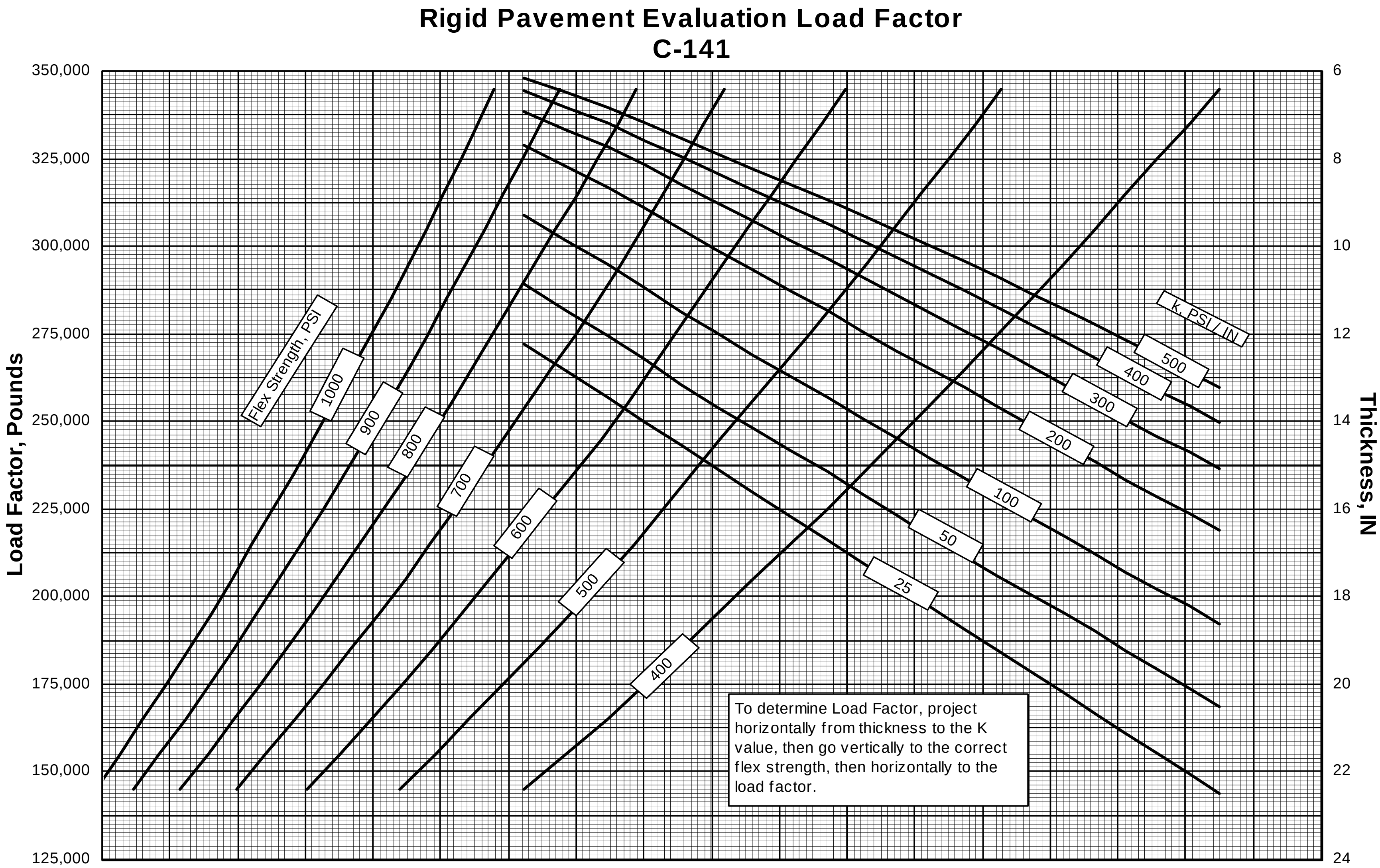




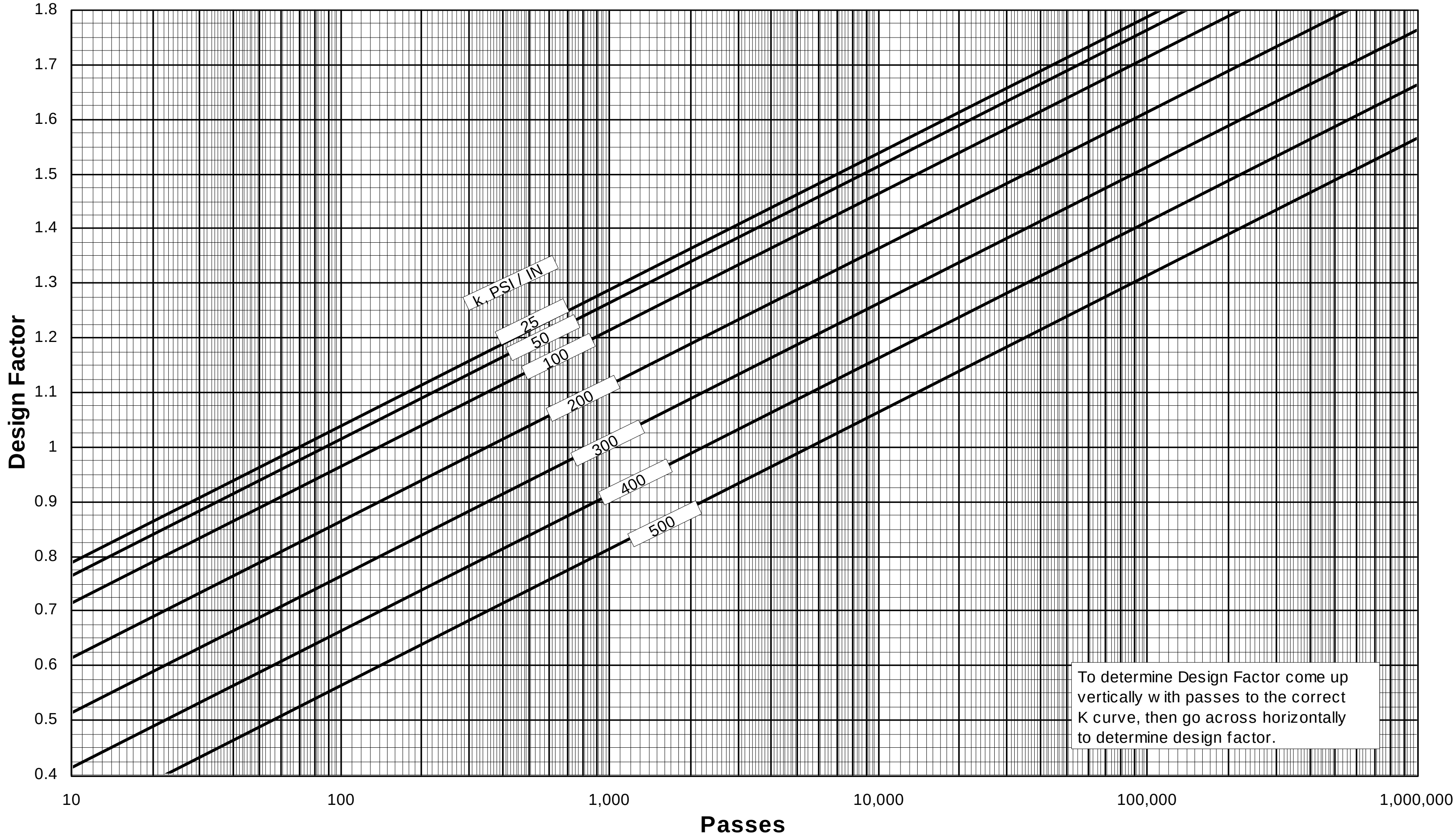
Rigid Design Factors For Extended Evaluation - A Traffic Area
C-130H
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
C-130H

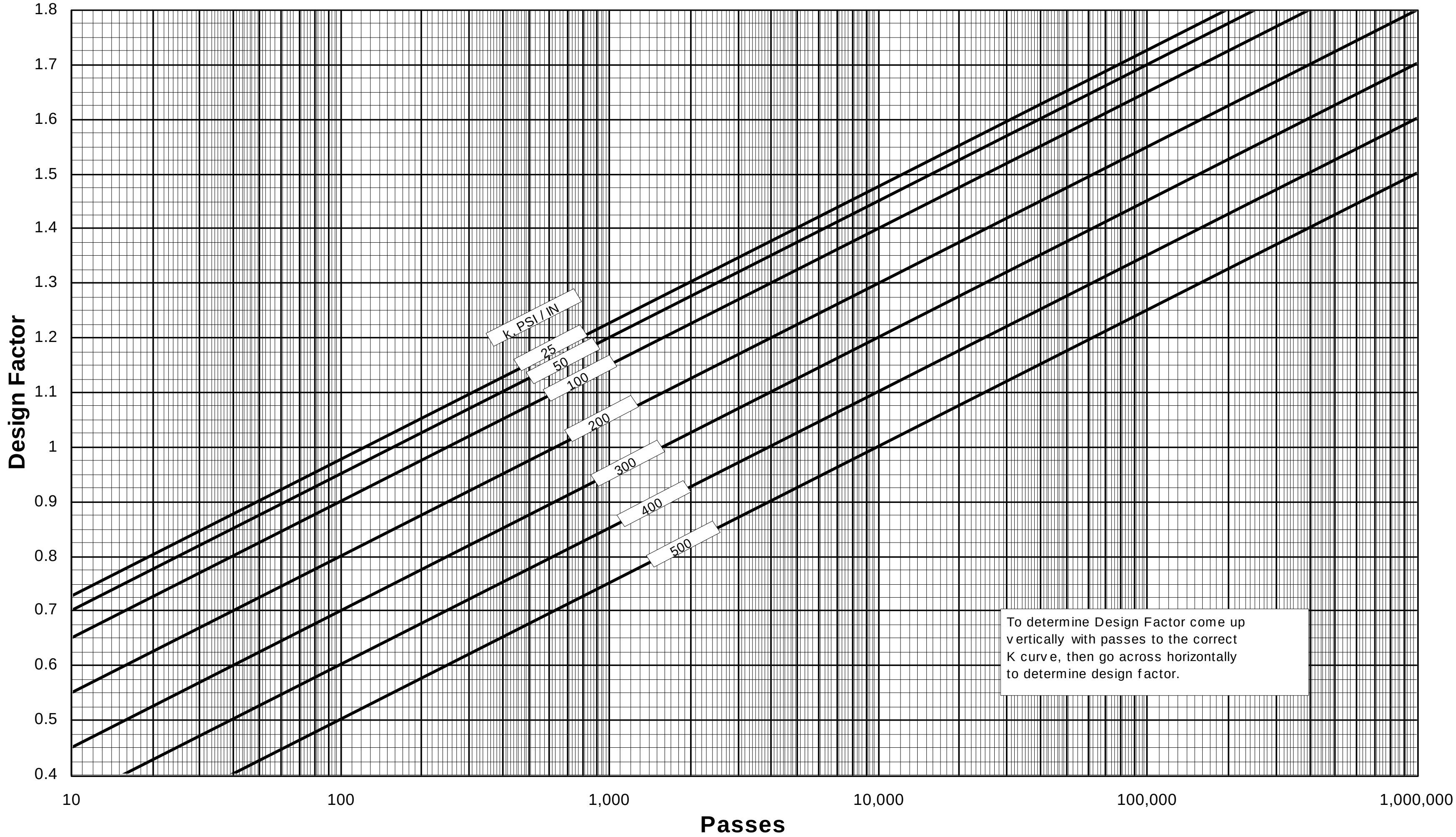


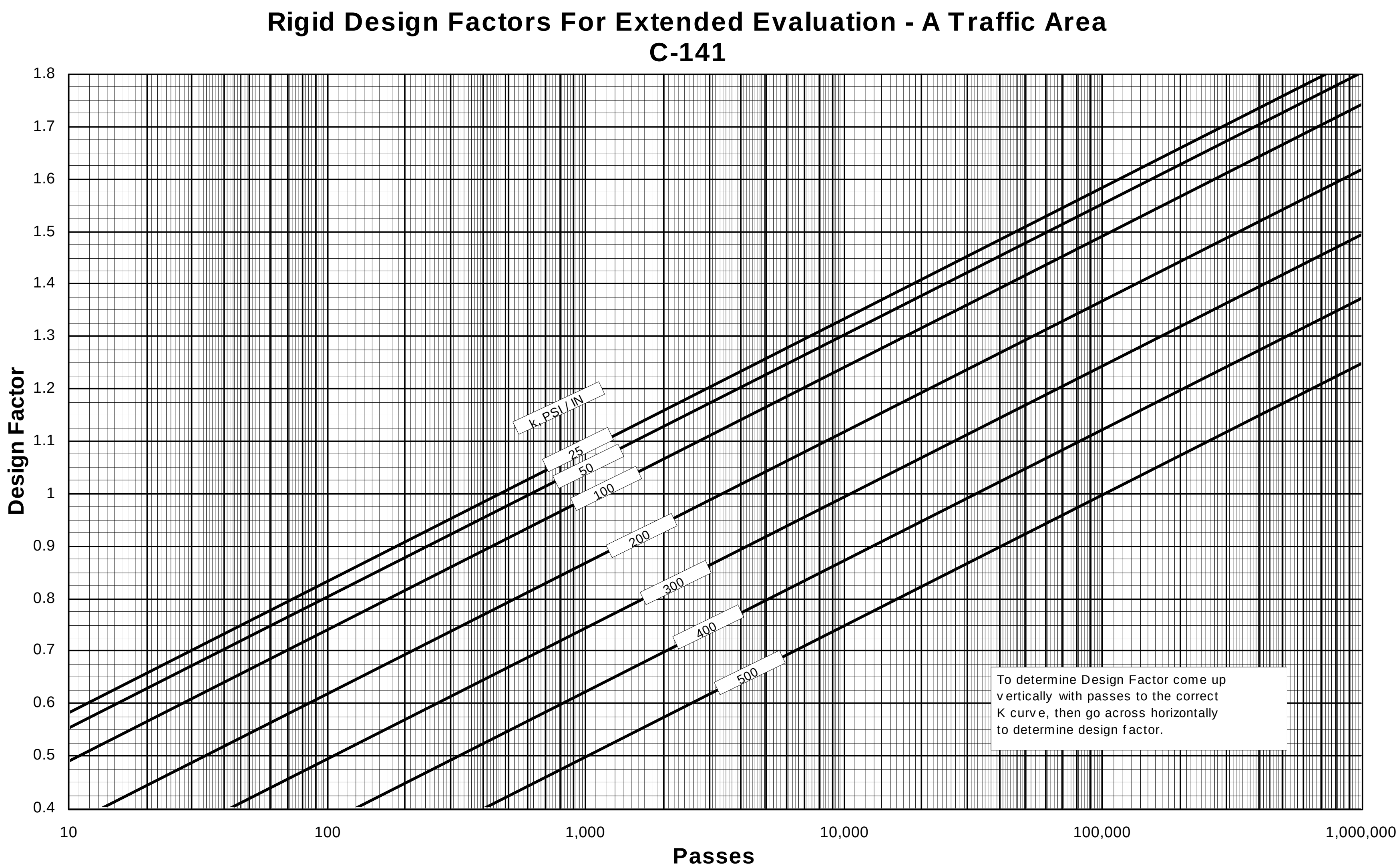

Rigid Pavement Evaluation Load Factor
C-141
350,000
325,000
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
Load Factor, Pounds
6
8
10
12
14
16
18
20
22
24
Thickness, IN
Flex Strength, PSI
1000
900
800
700
600
500
400
K, PSI / IN
500
400
300
200
100
50
25
To determine Load Factor, project horizontally from thickness to the K value, then go vertically to the correct flex strength, then horizontally to the load factor.

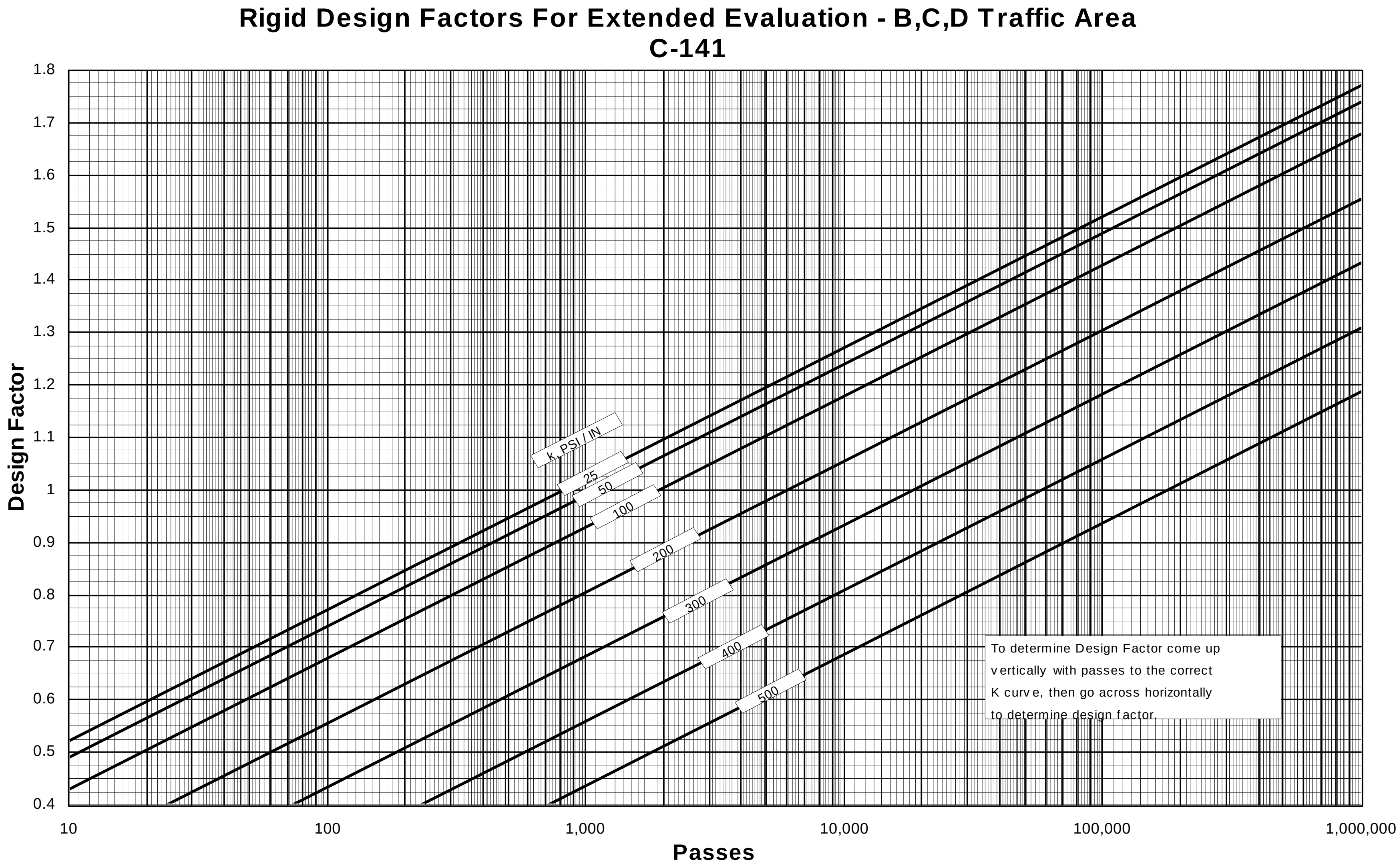
Rigid Design Factors For Standard Evaluation - A Traffic Area
C-141



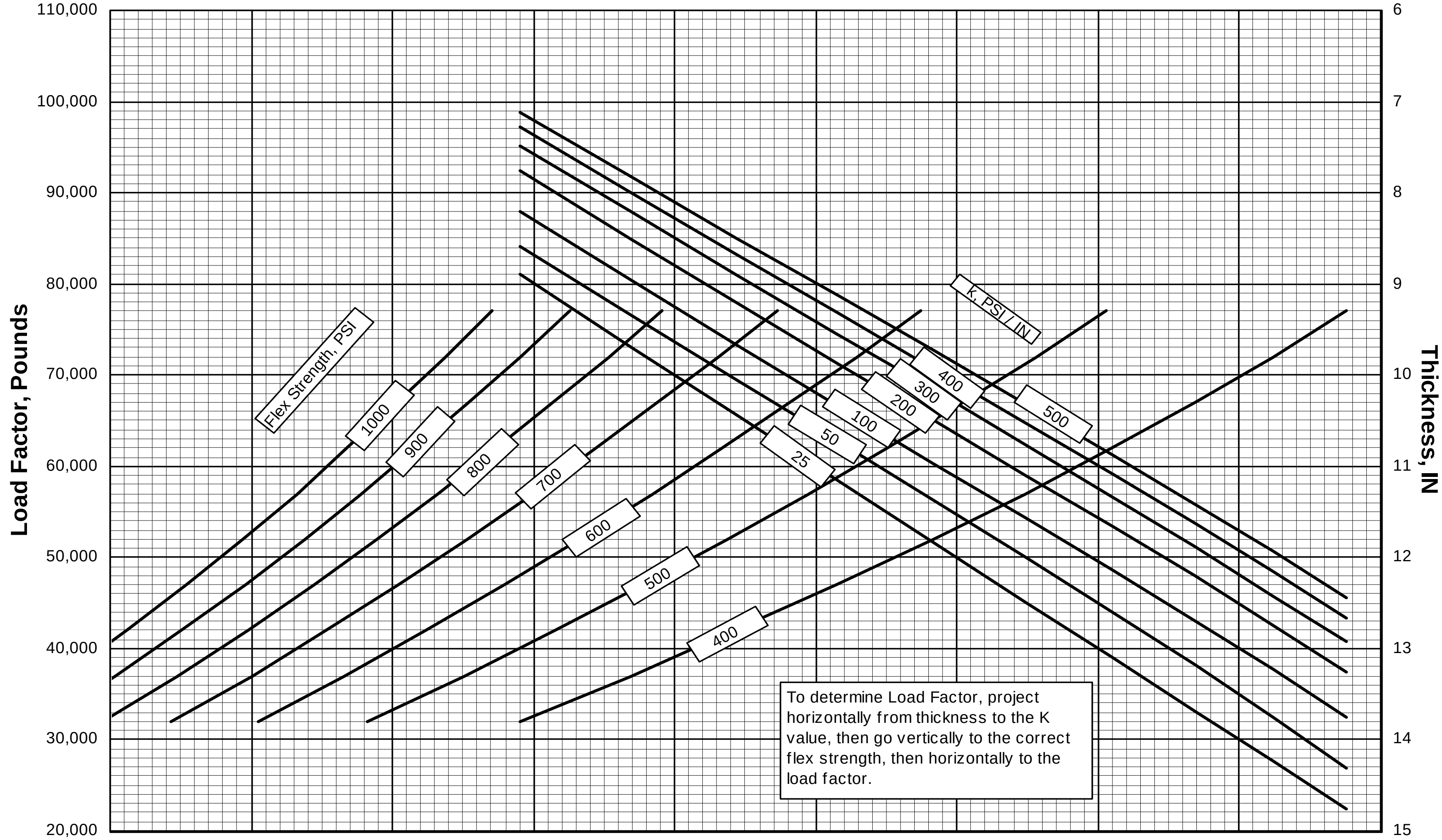
Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
C-141

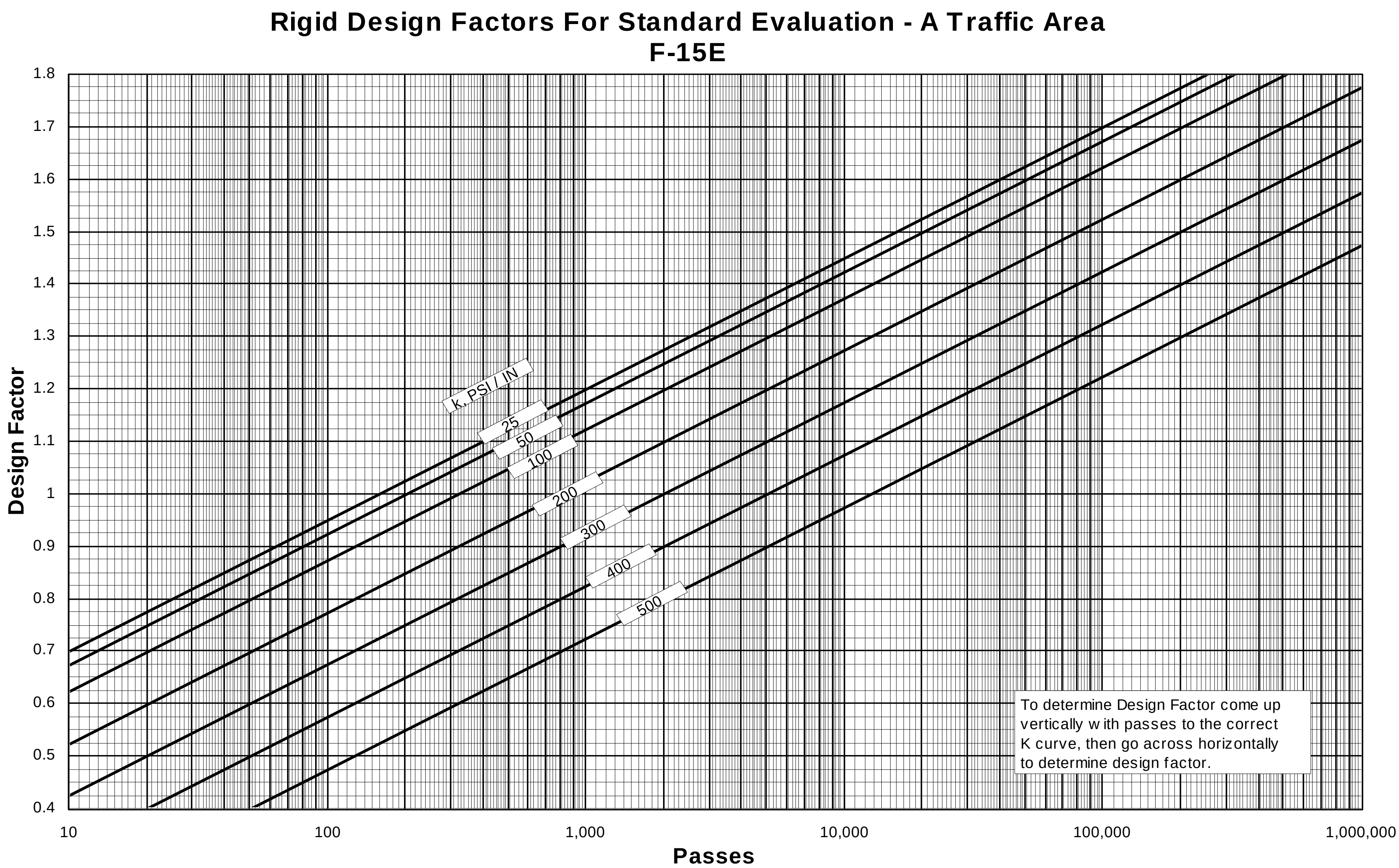



Rigid Design Factors For Extended Evaluation - A Traffic Area
C-141
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

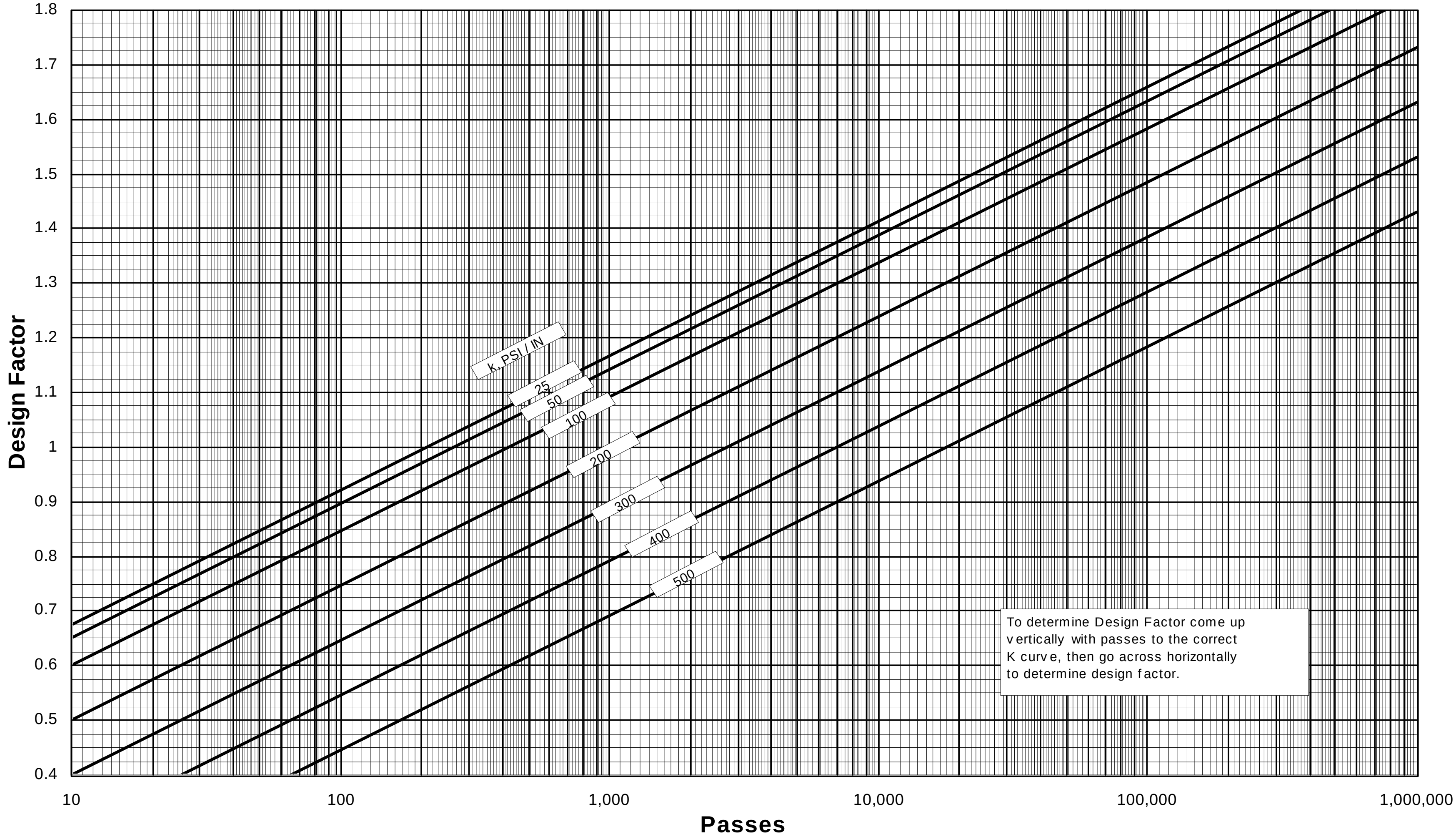

Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
C-141
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

Rigid Pavement Evaluation Load Factor
F-15E

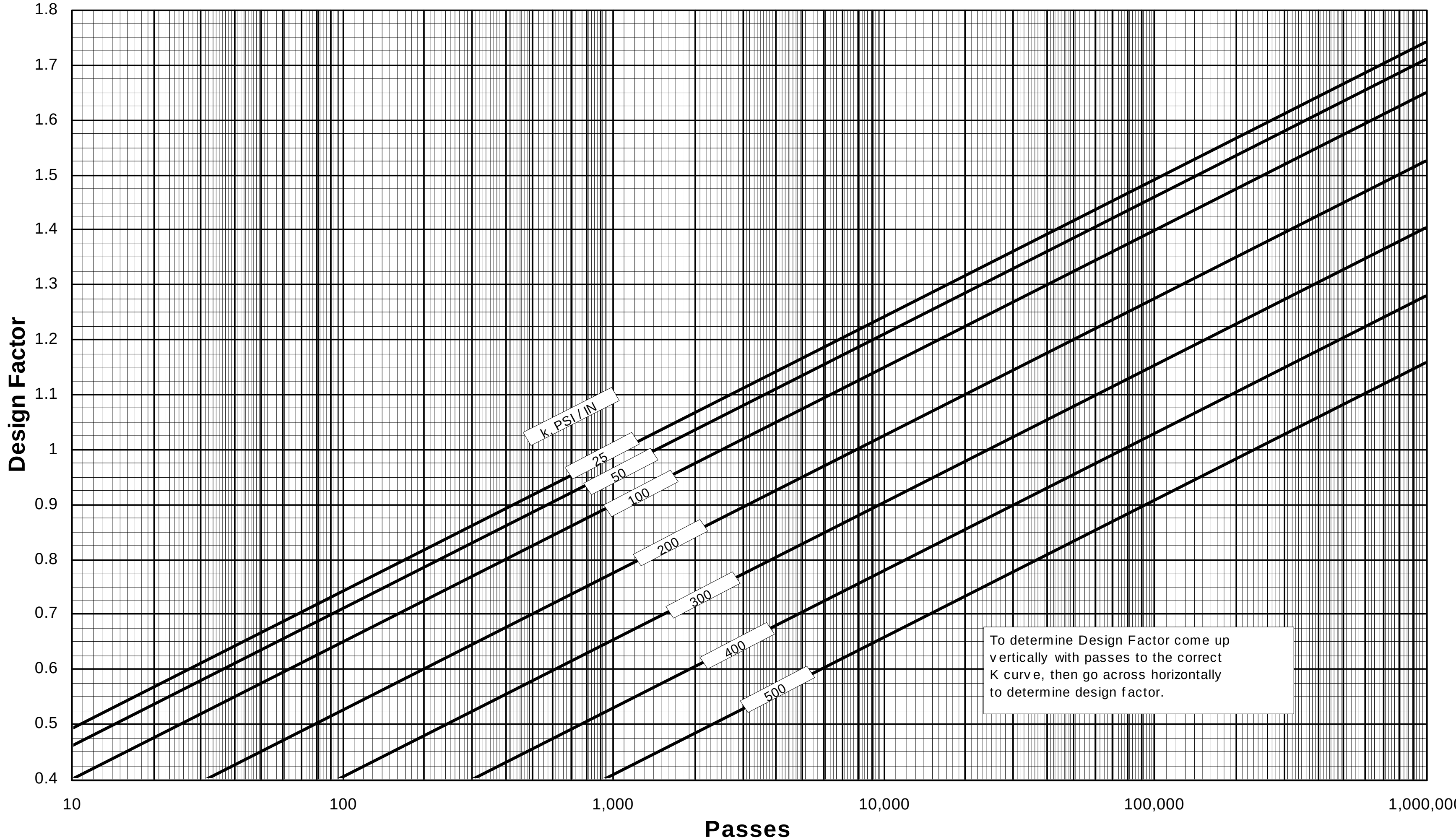



Rigid Design Factors For Standard Evaluation - A Traffic Area
F-15E
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically w ith passes to the correct K curve, then go across horizontally to determine design factor.

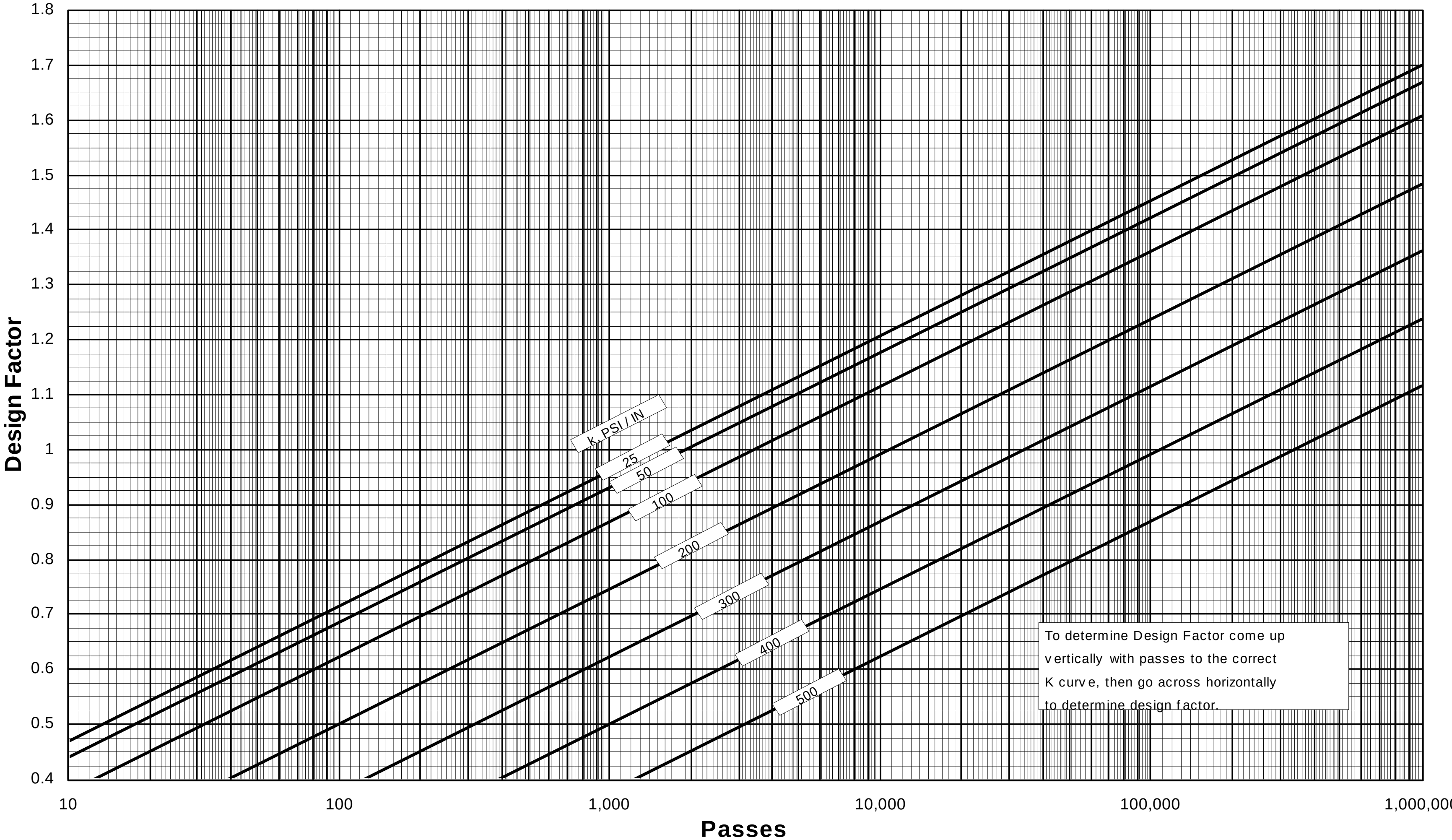
Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
F-15E



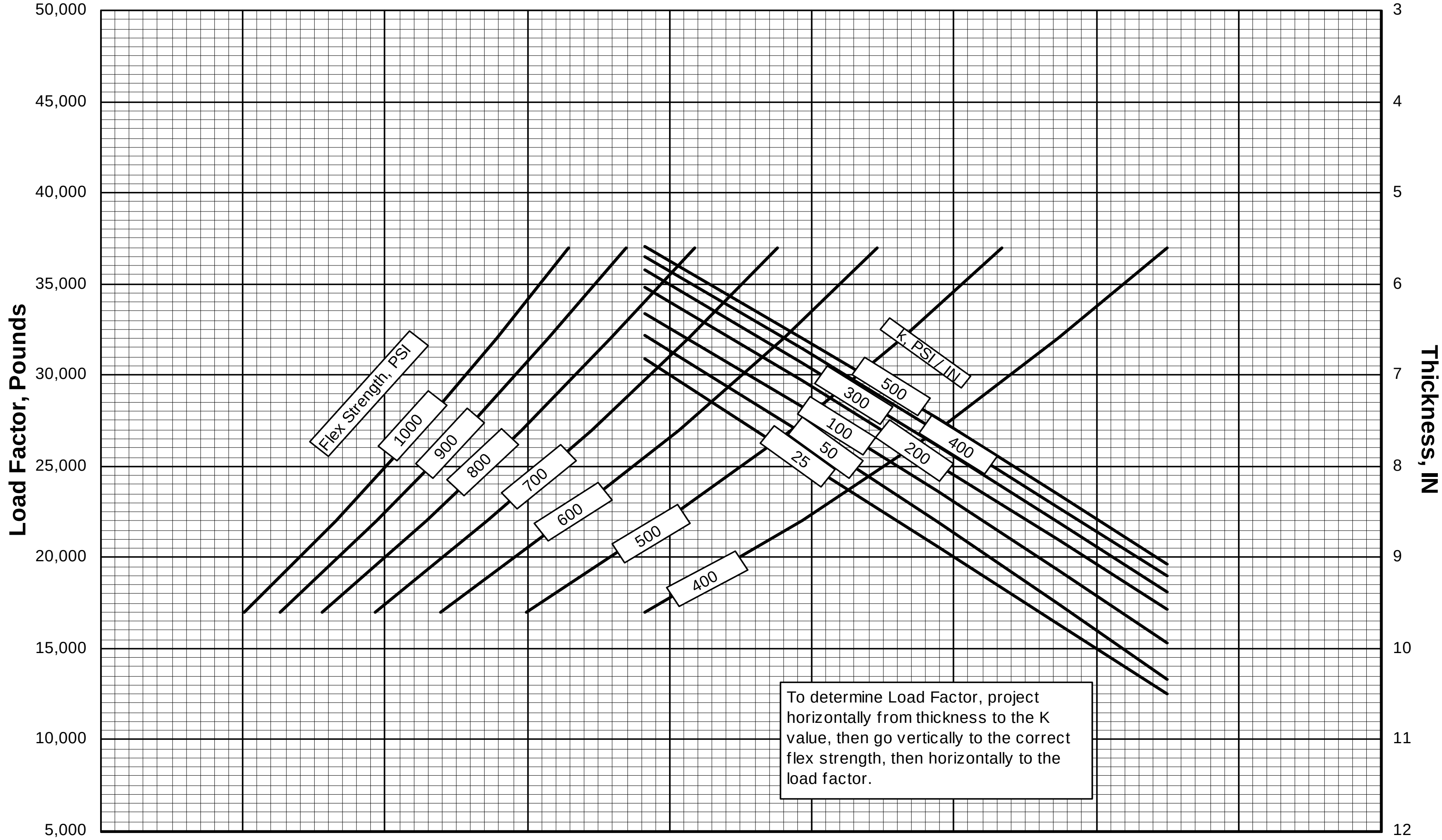
Rigid Design Factors For Extended Evaluation - A Traffic Area
F-15E



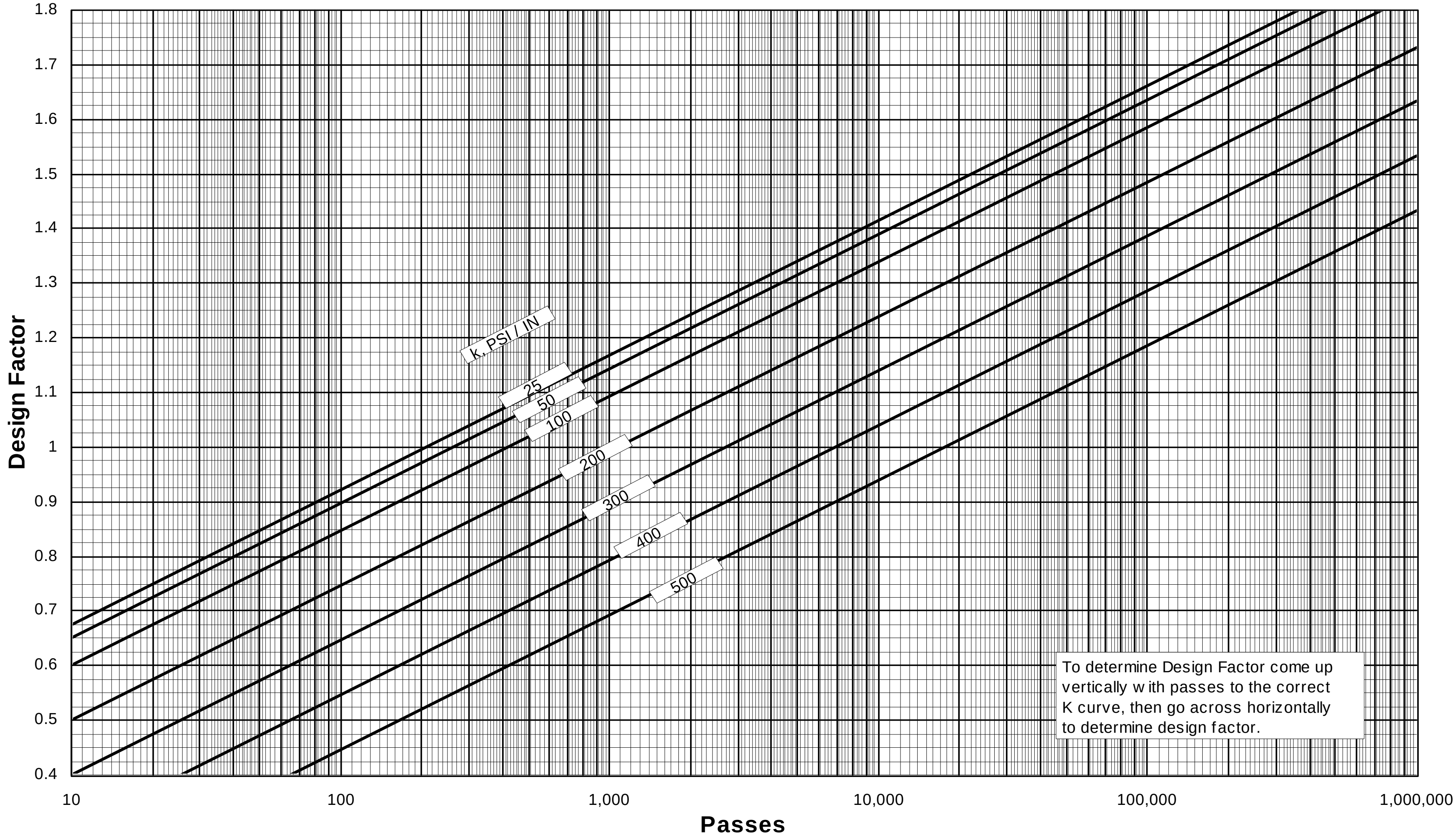
Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
F-15E



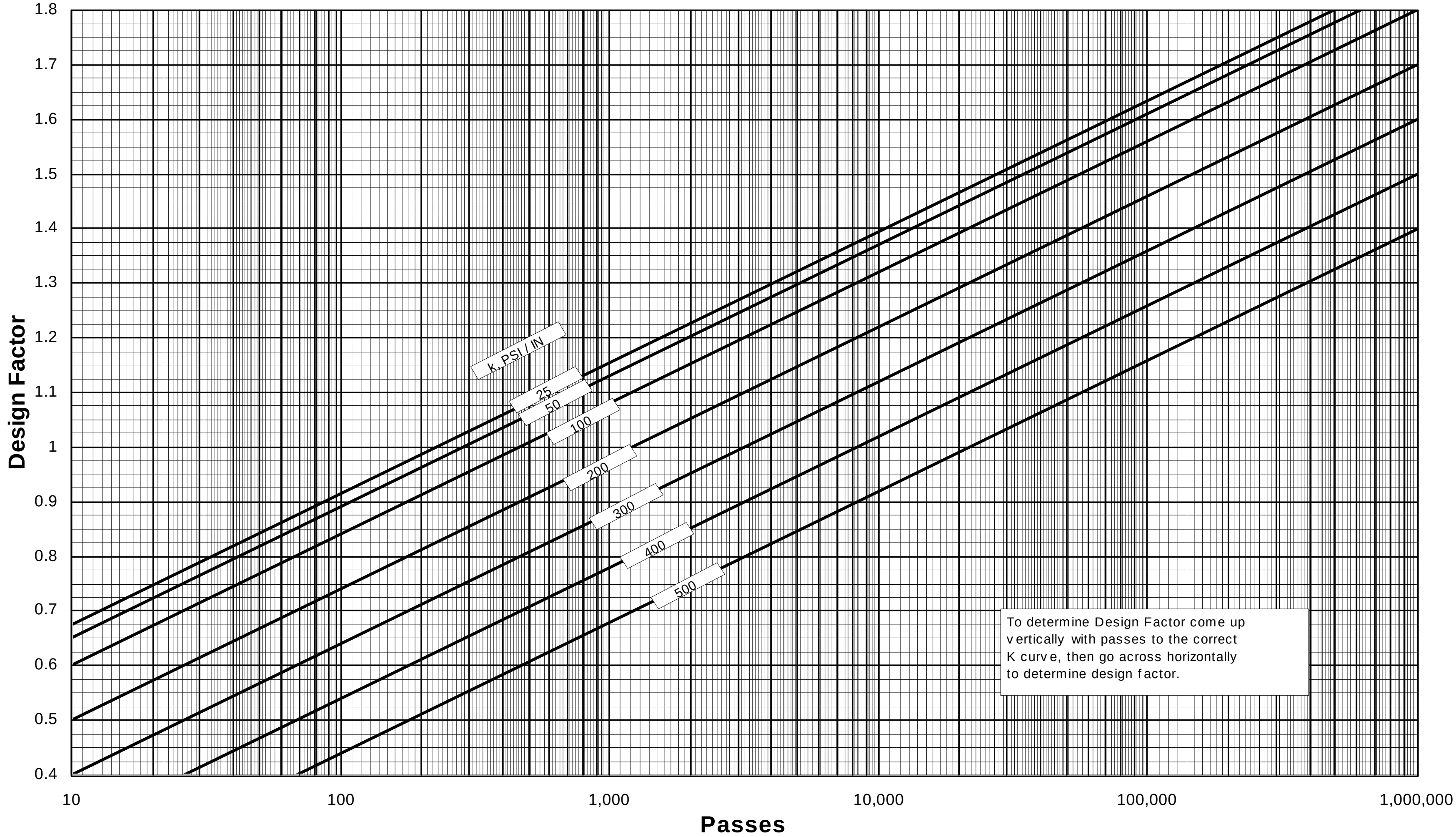
Rigid Pavement Evaluation Load Factor
F-16C/D



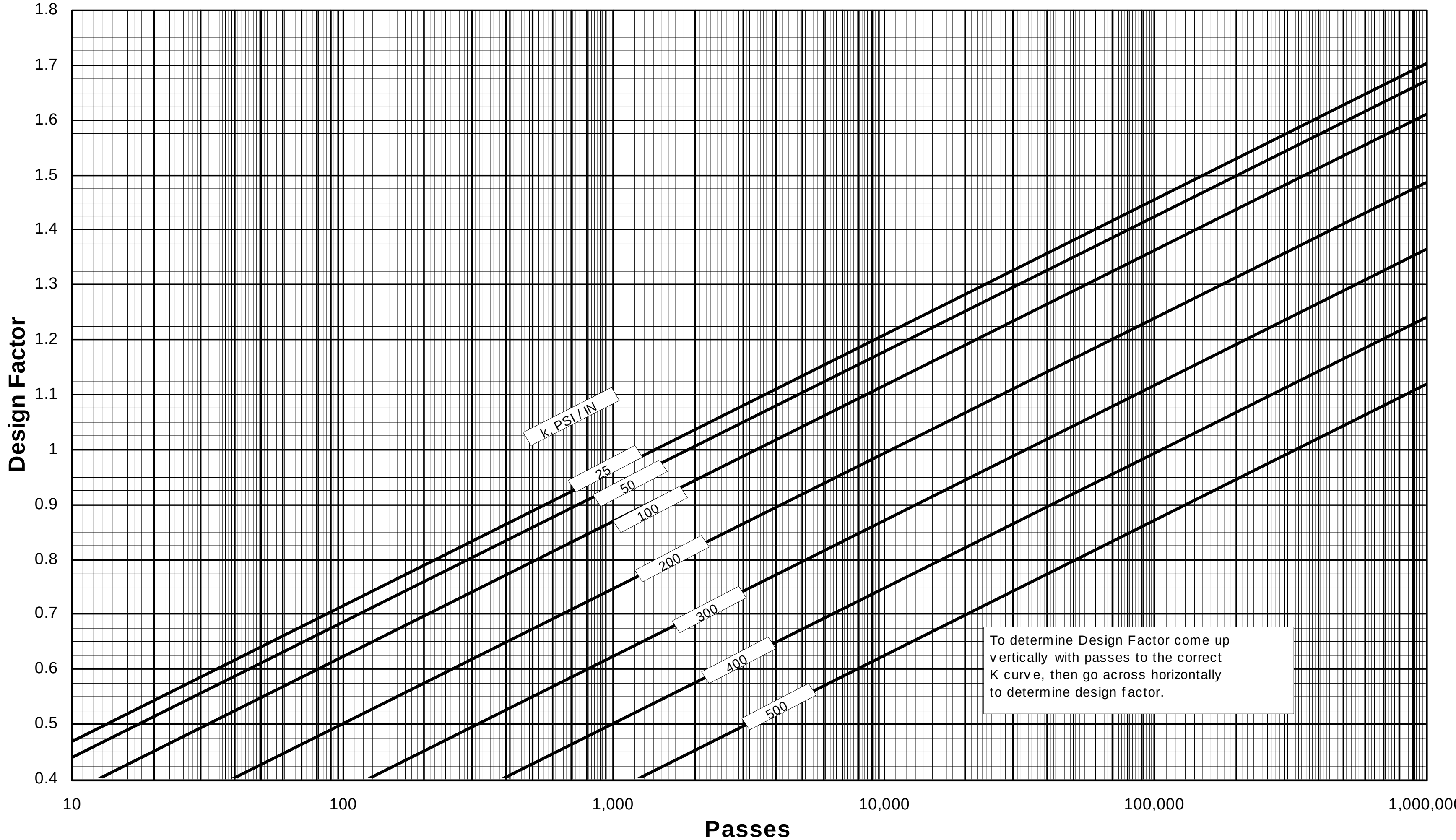
Rigid Design Factors For Standard Evaluation - A Traffic Area
F-16C/D

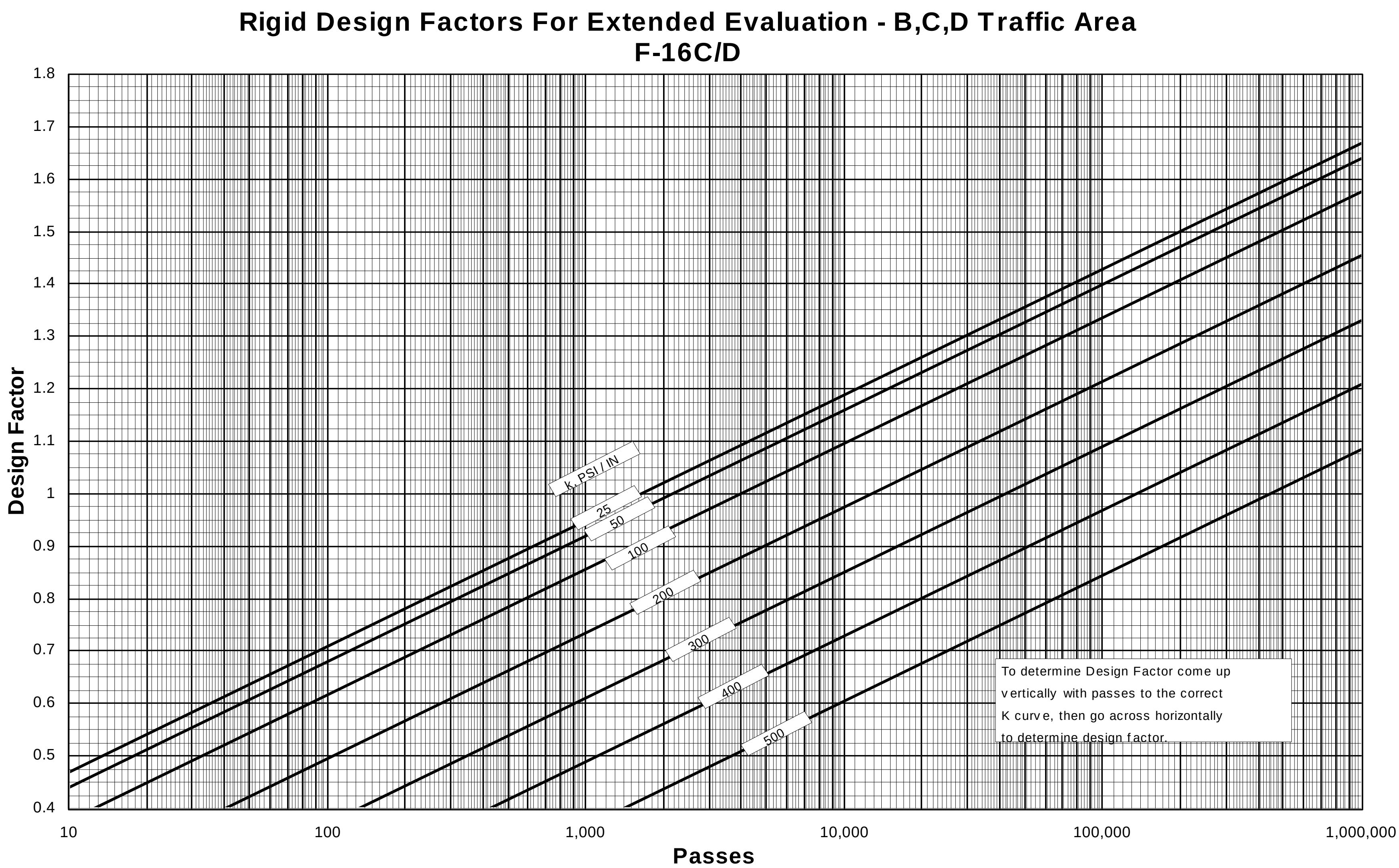


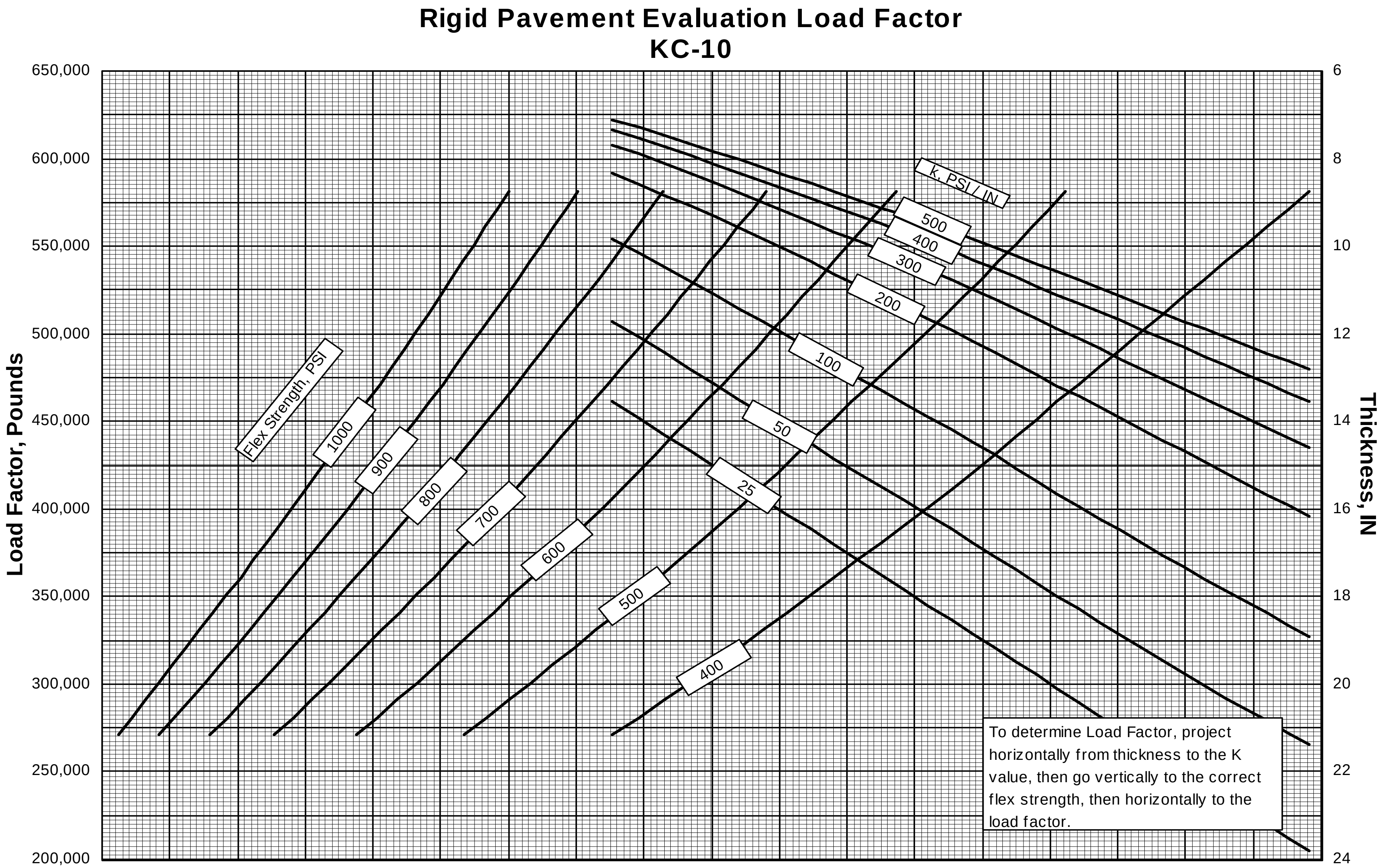
Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
F-16C/D

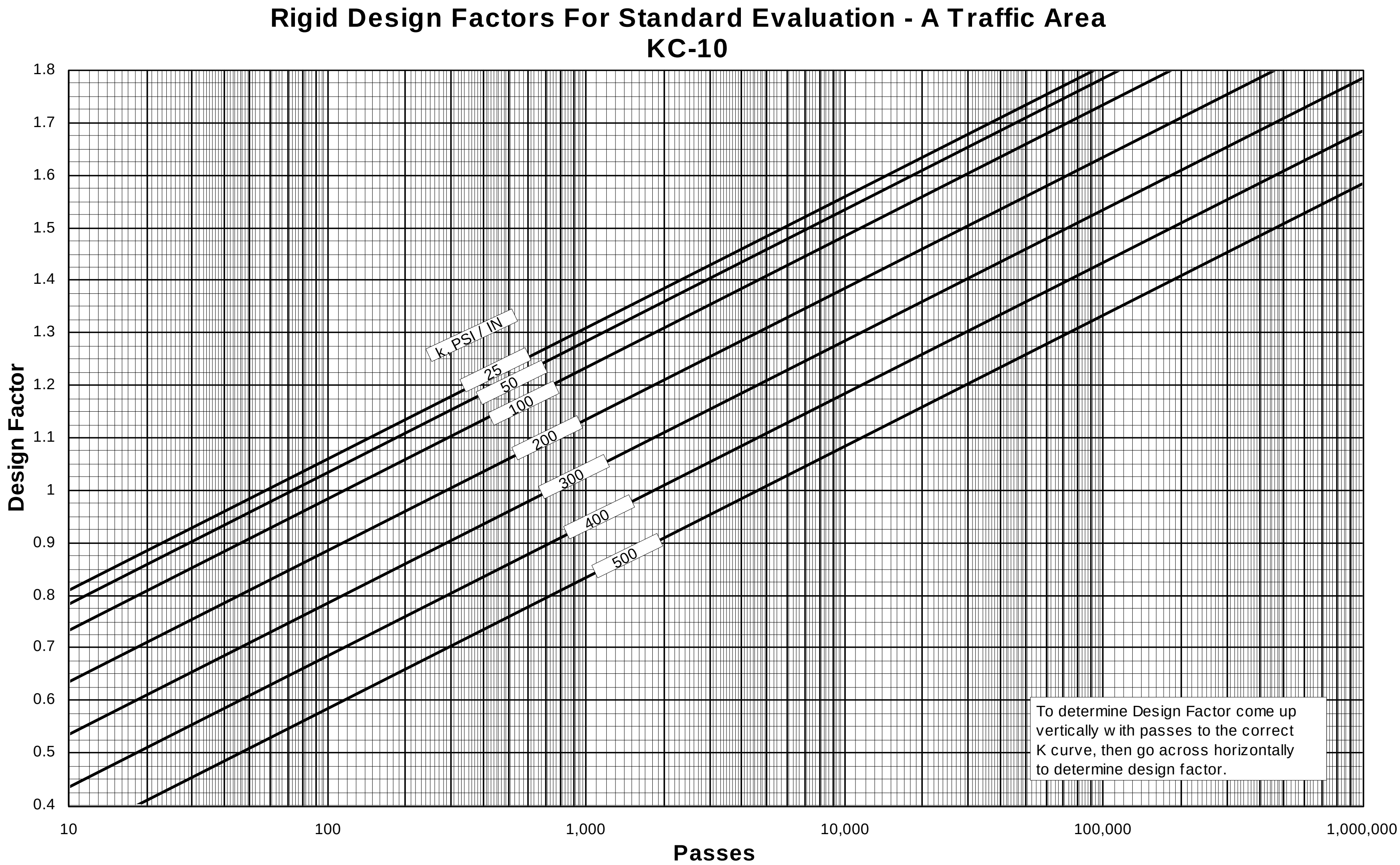


Rigid Design Factors For Extended Evaluation - A Traffic Area
F-16C/D

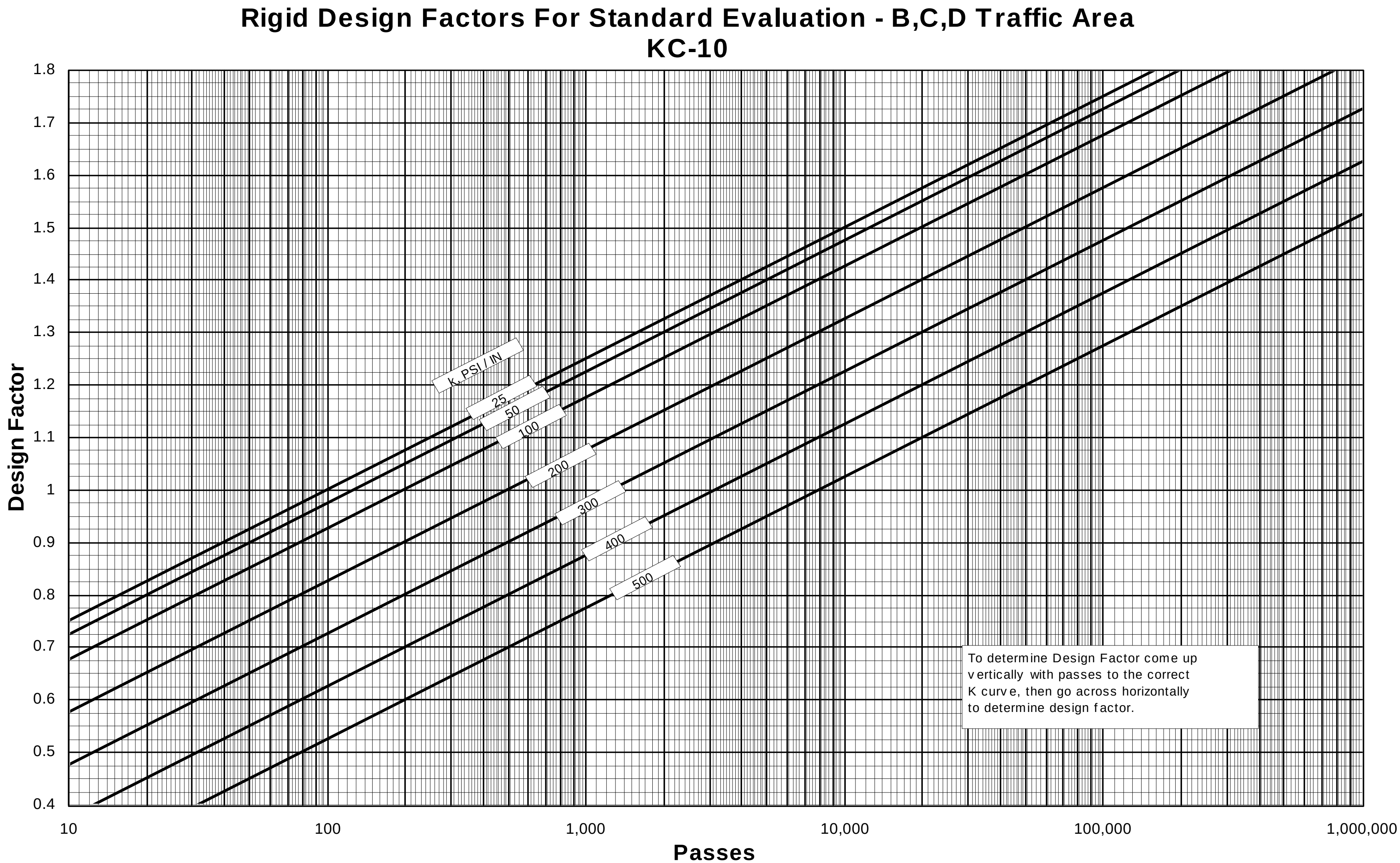



Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
F-16C/D
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

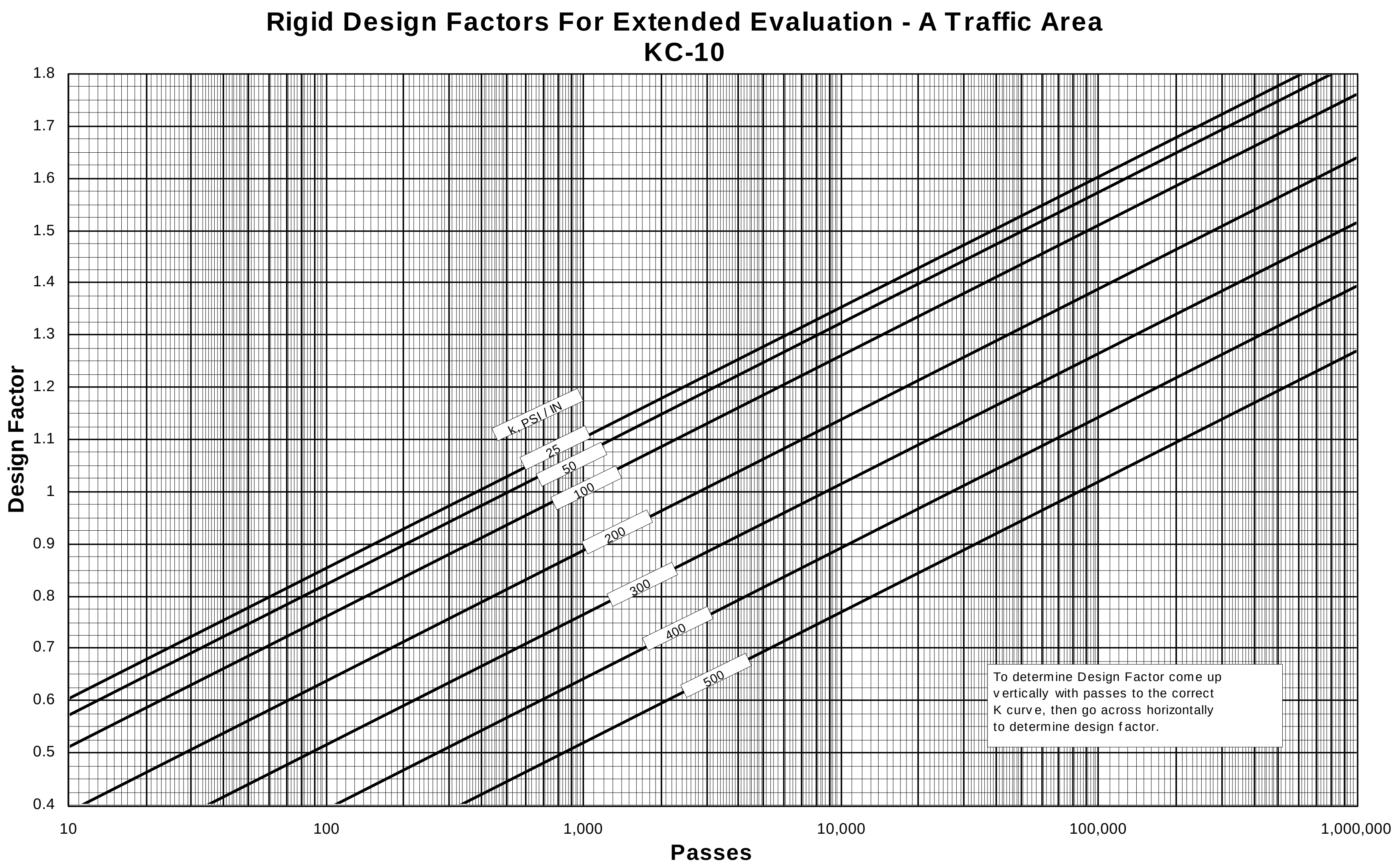

Rigid Pavement Evaluation Load Factor
KC-10
Load Factor, Pounds
650,000
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
Thickness, IN
6
8
10
12
14
16
18
20
22
24
Flex Strength, PSI
1000
900
800
700
600
500
400
K, PSI / IN
500
400
300
200
100
50
25
To determine Load Factor, project horizontally from thickness to the K value, then go vertically to the correct flex strength, then horizontally to the load factor.



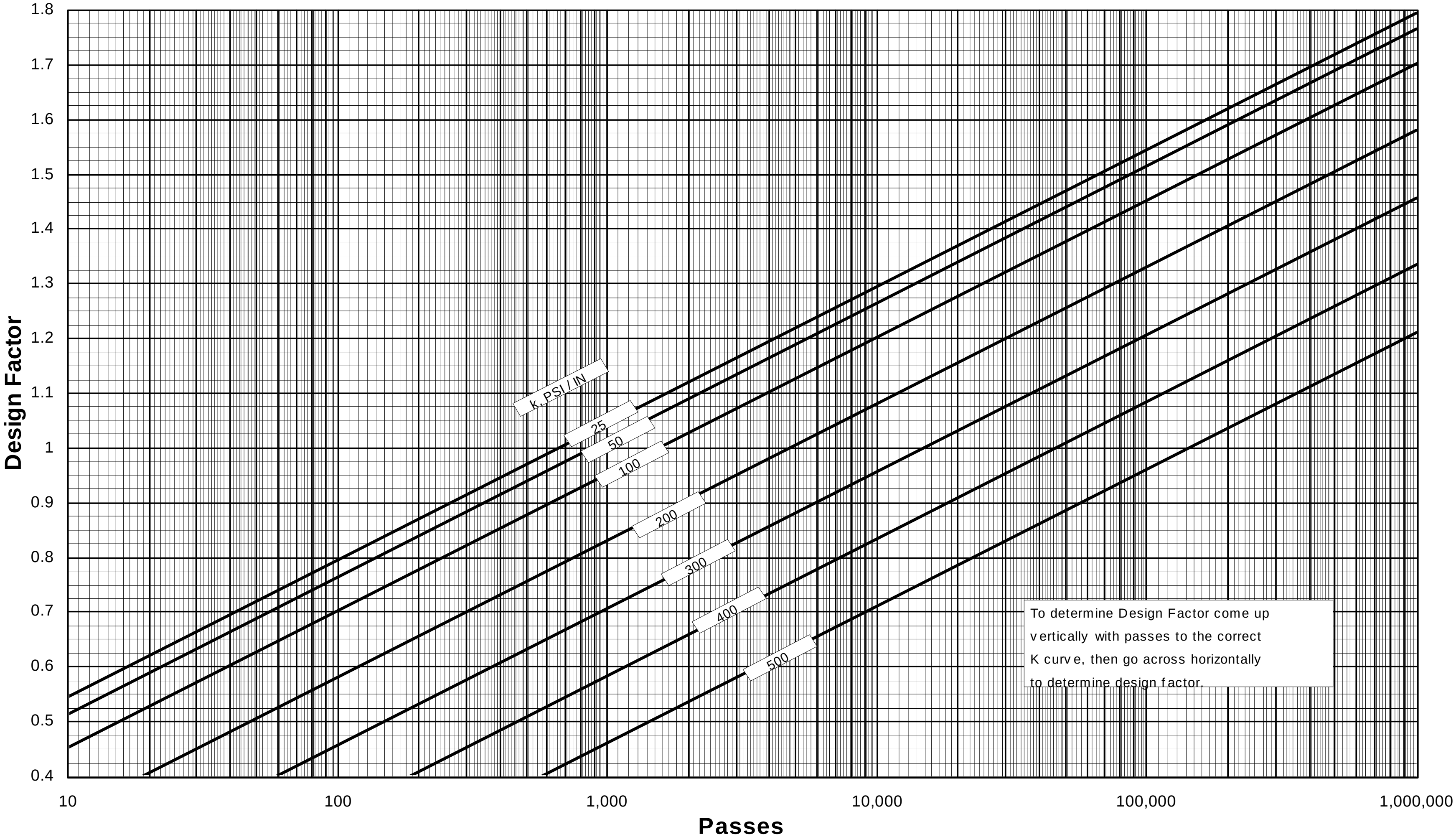
Rigid Design Factors For Standard Evaluation - A Traffic Area
KC-10
Design Factor
Passes
k, PSI / IN
25
50
100
200
300
400
500
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
To determine Design Factor come up vertically w ith passes to the correct K curve, then go across horizontally to determine design factor.

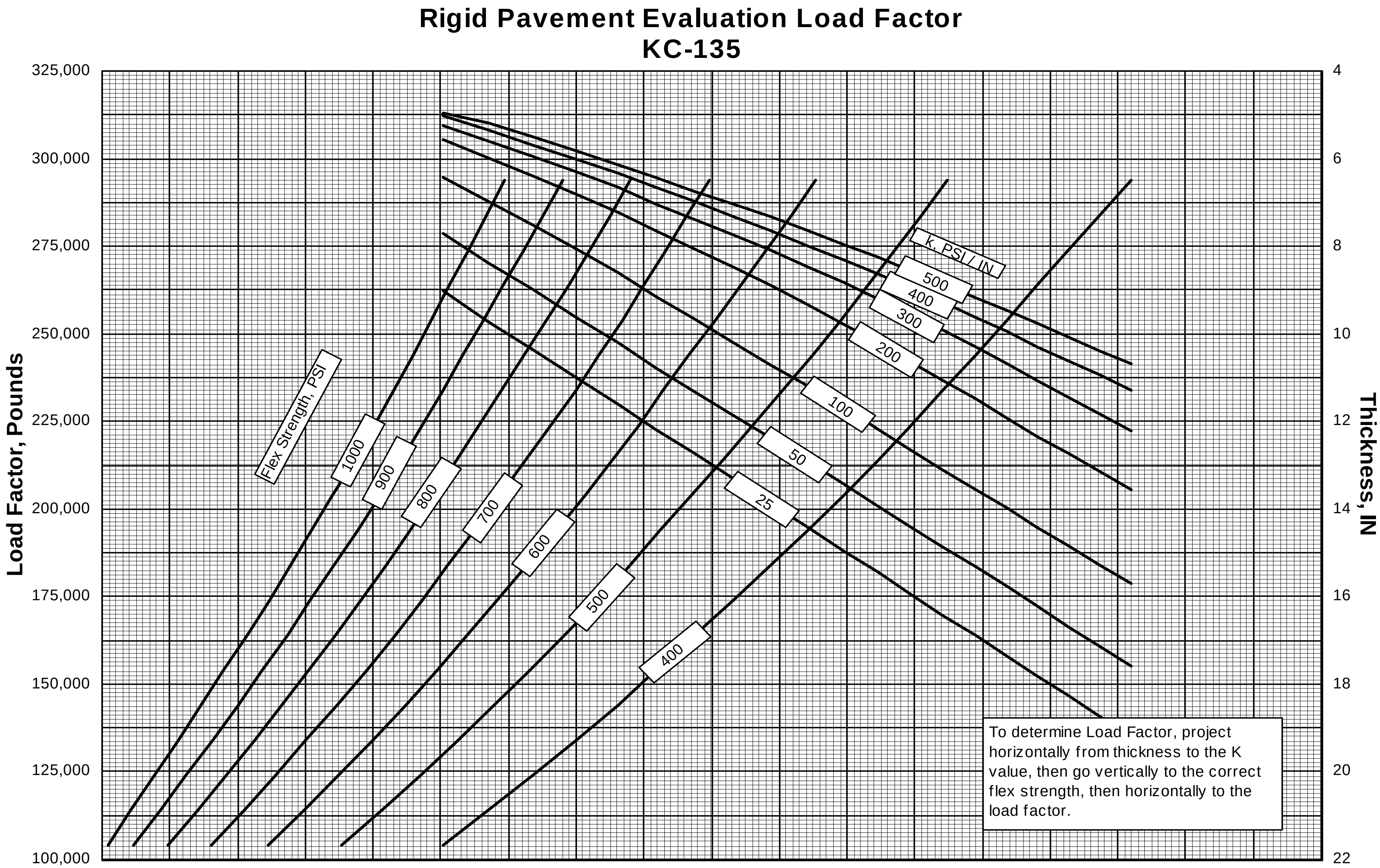


Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
KC-10
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
K, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

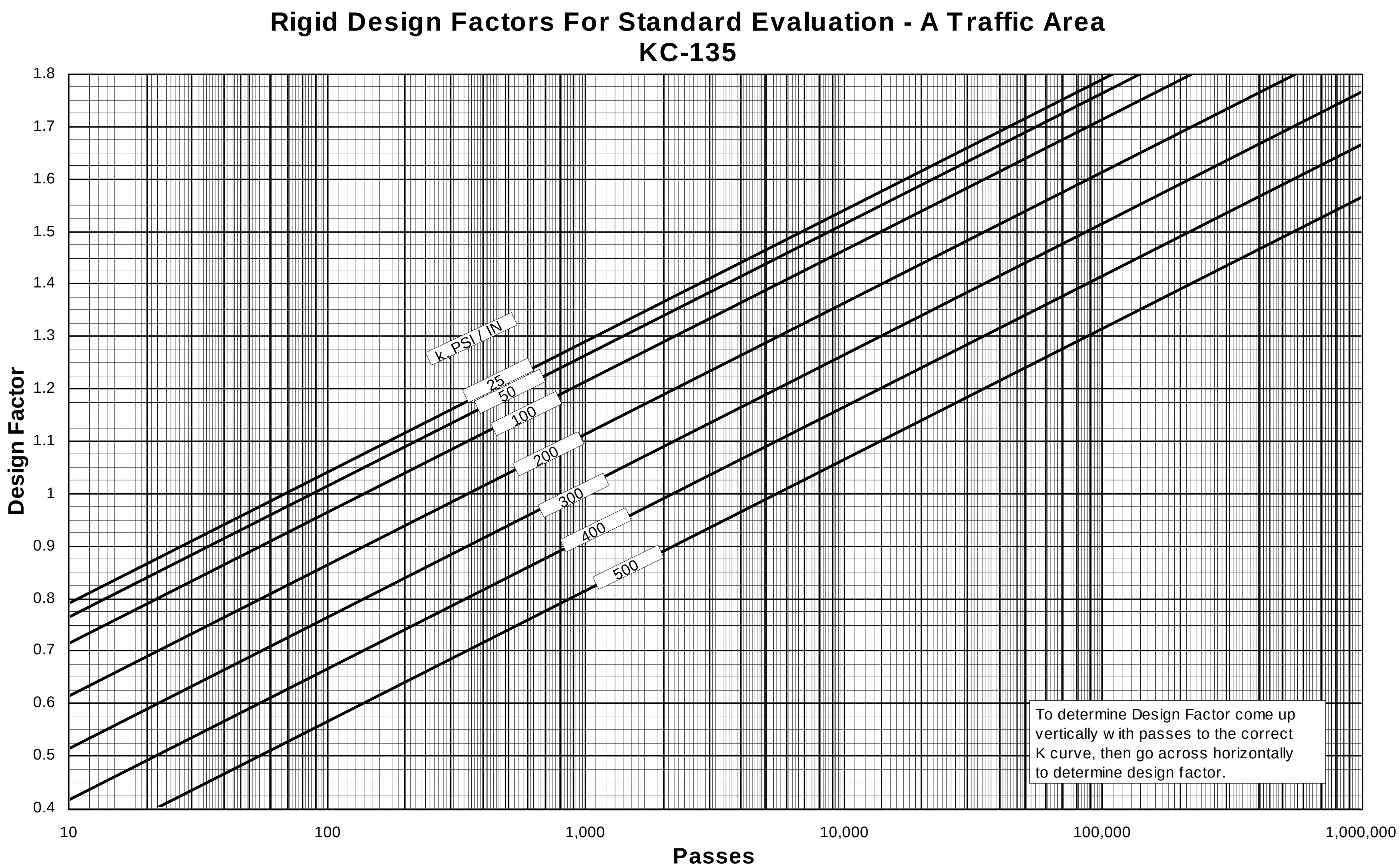

Rigid Design Factors For Extended Evaluation - A Traffic Area
KC-10
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
KC-10

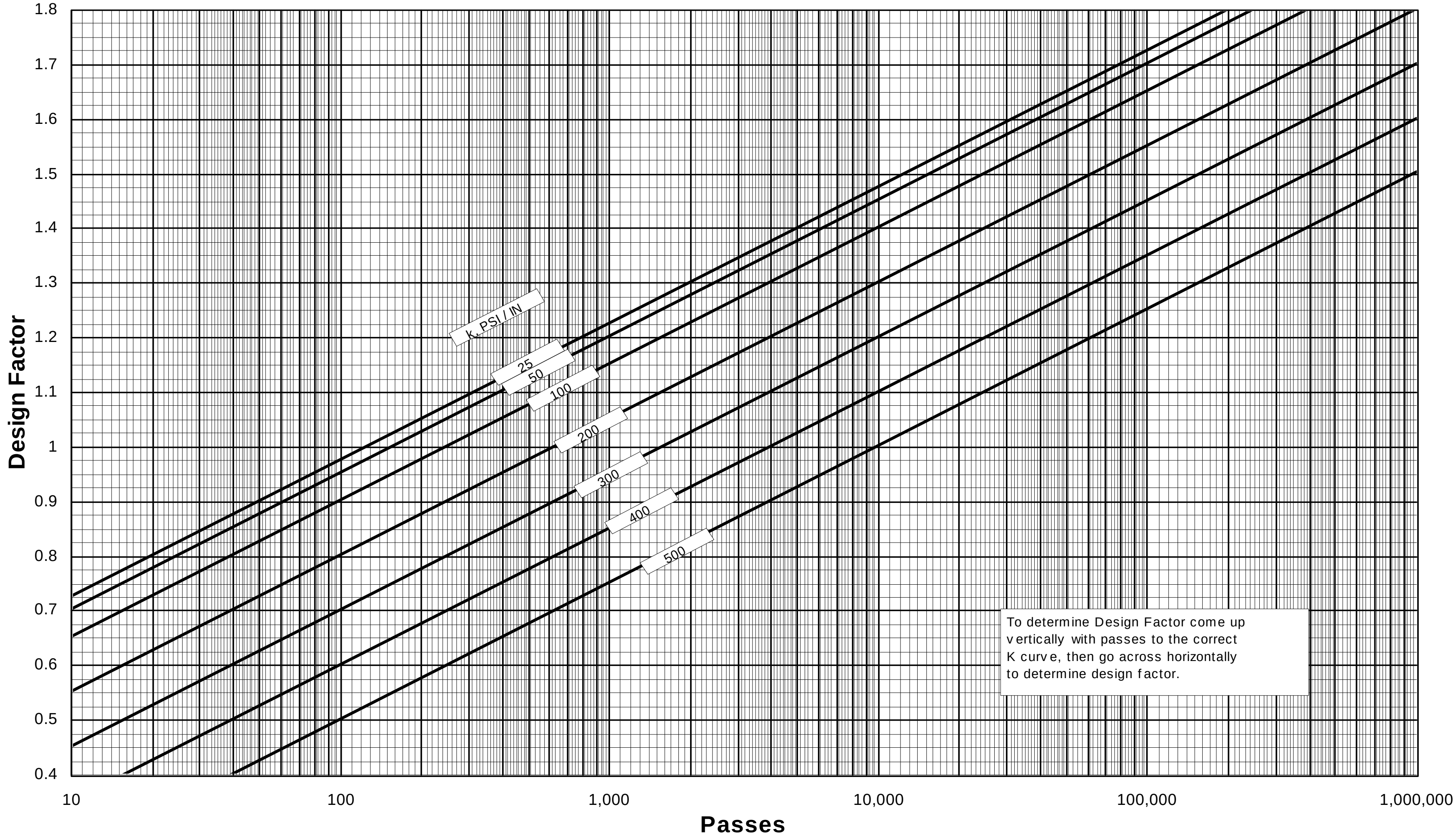


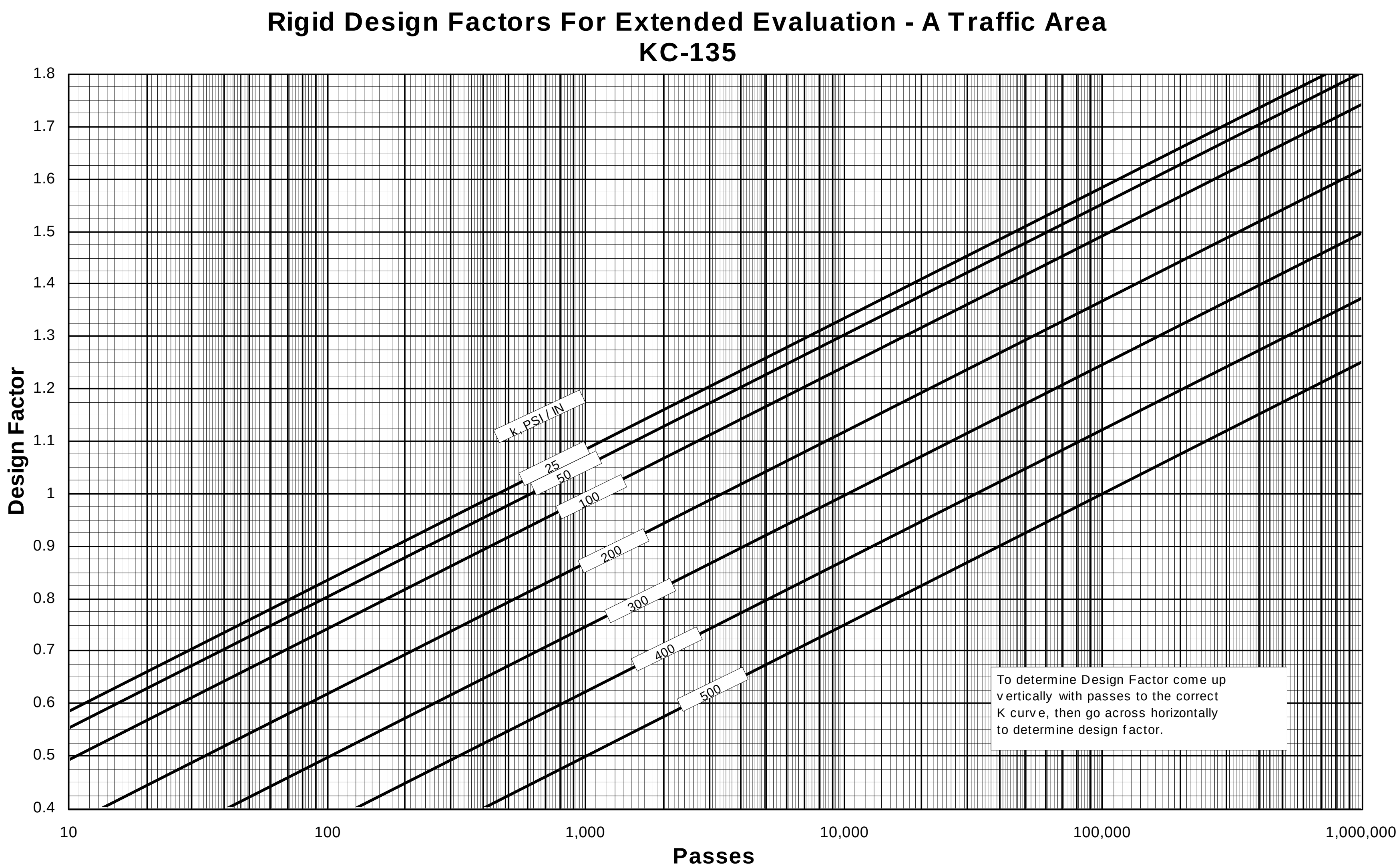


Rigid Pavement Evaluation Load Factor
KC-135
Load Factor, Pounds
325,000
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
Thickness, IN
4
6
8
10
12
14
16
18
20
22
k, PSI / IN
500
400
300
200
100
50
25
Flex Strength, PSI
1000
900
800
700
600
500
400
To determine Load Factor, project horizontally from thickness to the K value, then go vertically to the correct flex strength, then horizontally to the load factor.

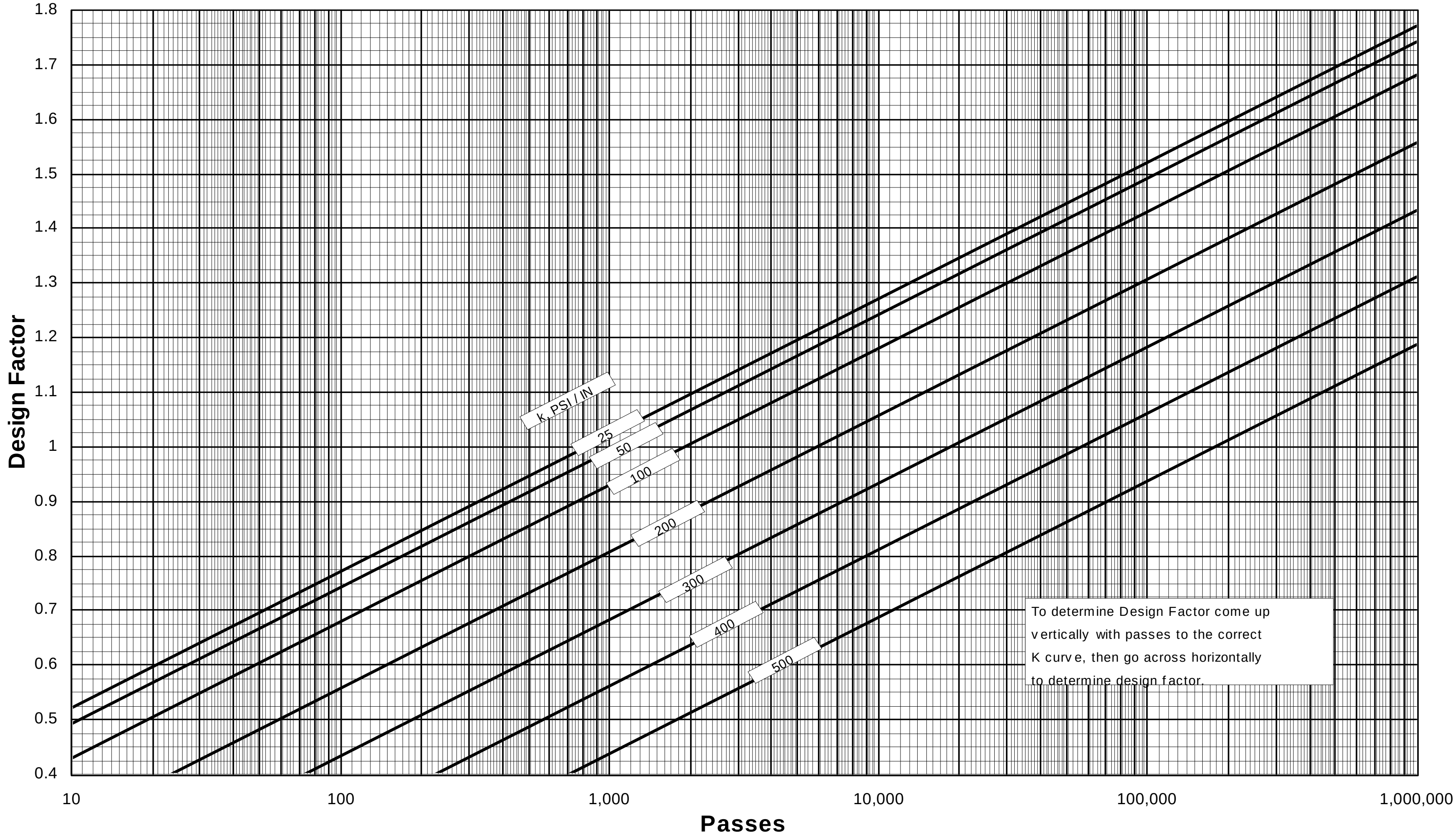

Rigid Design Factors For Standard Evaluation - A Traffic Area
KC-135
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically w ith passes to the correct K curve, then go across horizontally to determine design factor.

Rigid Design Factors For Standard Evaluation - B,C,D Traffic Area
KC-135

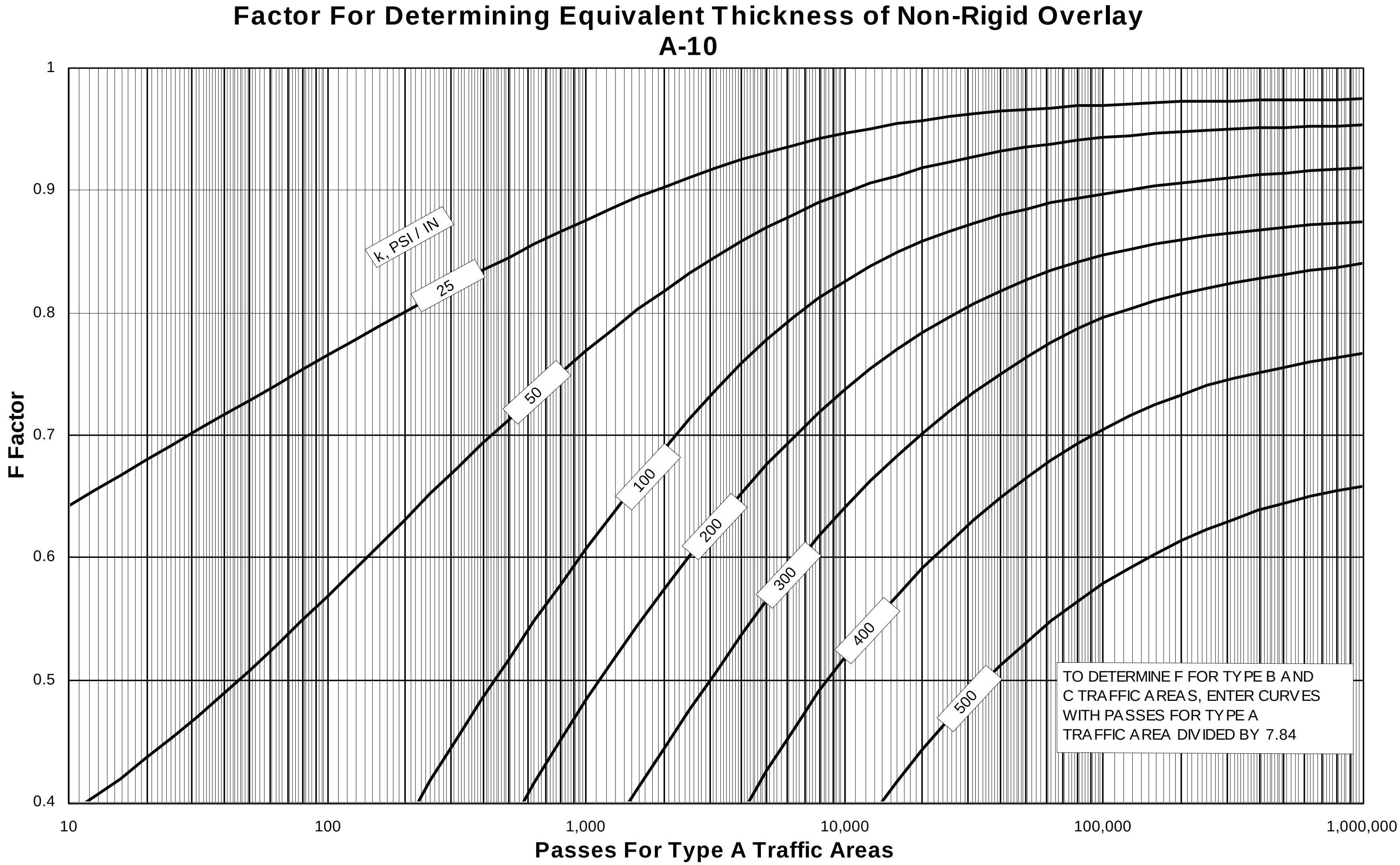



Rigid Design Factors For Extended Evaluation - A Traffic Area
KC-135
Design Factor
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
Passes
k, PSI / IN
25
50
100
200
300
400
500
To determine Design Factor come up vertically with passes to the correct K curve, then go across horizontally to determine design factor.

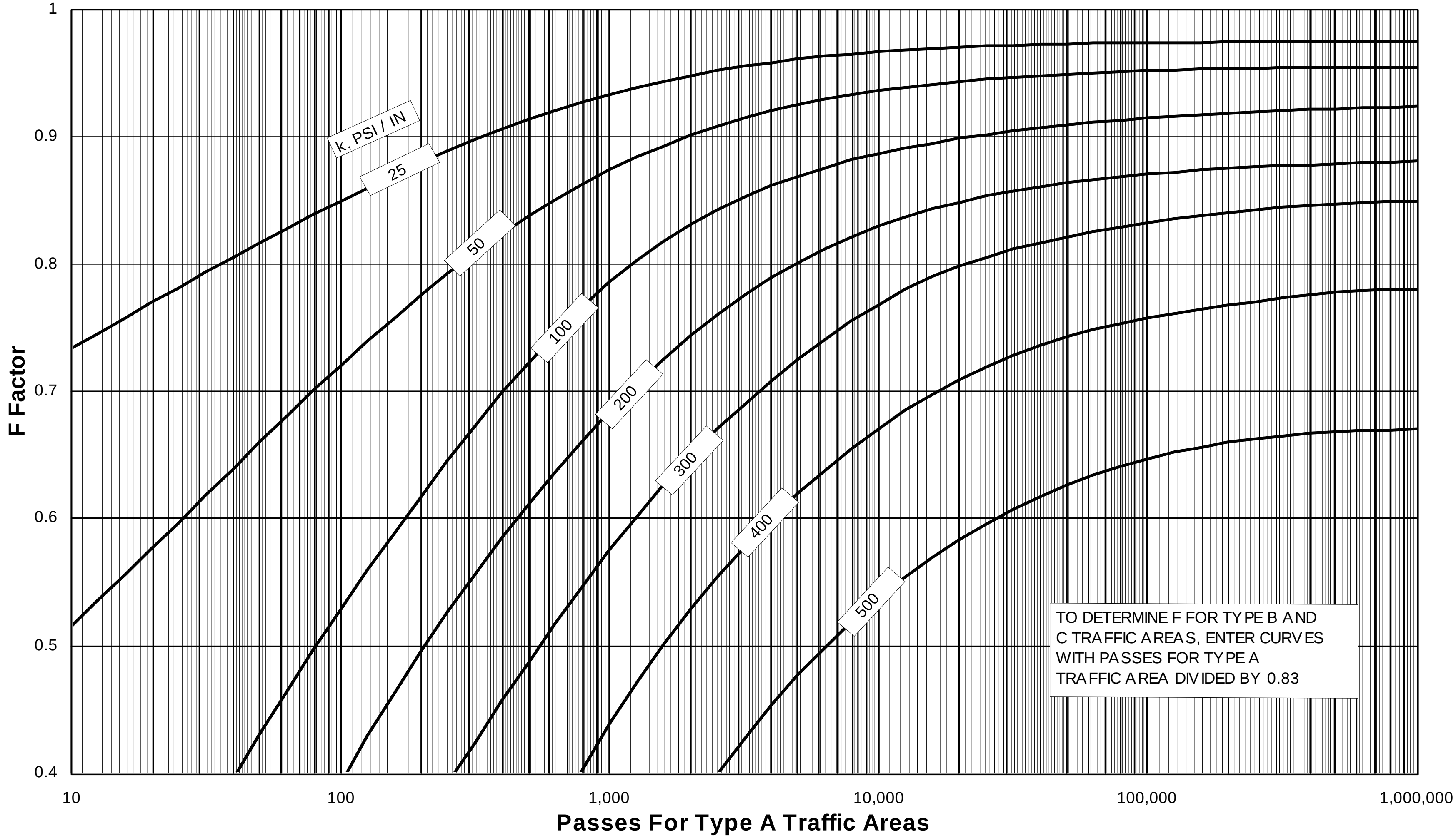
Rigid Design Factors For Extended Evaluation - B,C,D Traffic Area
KC-135



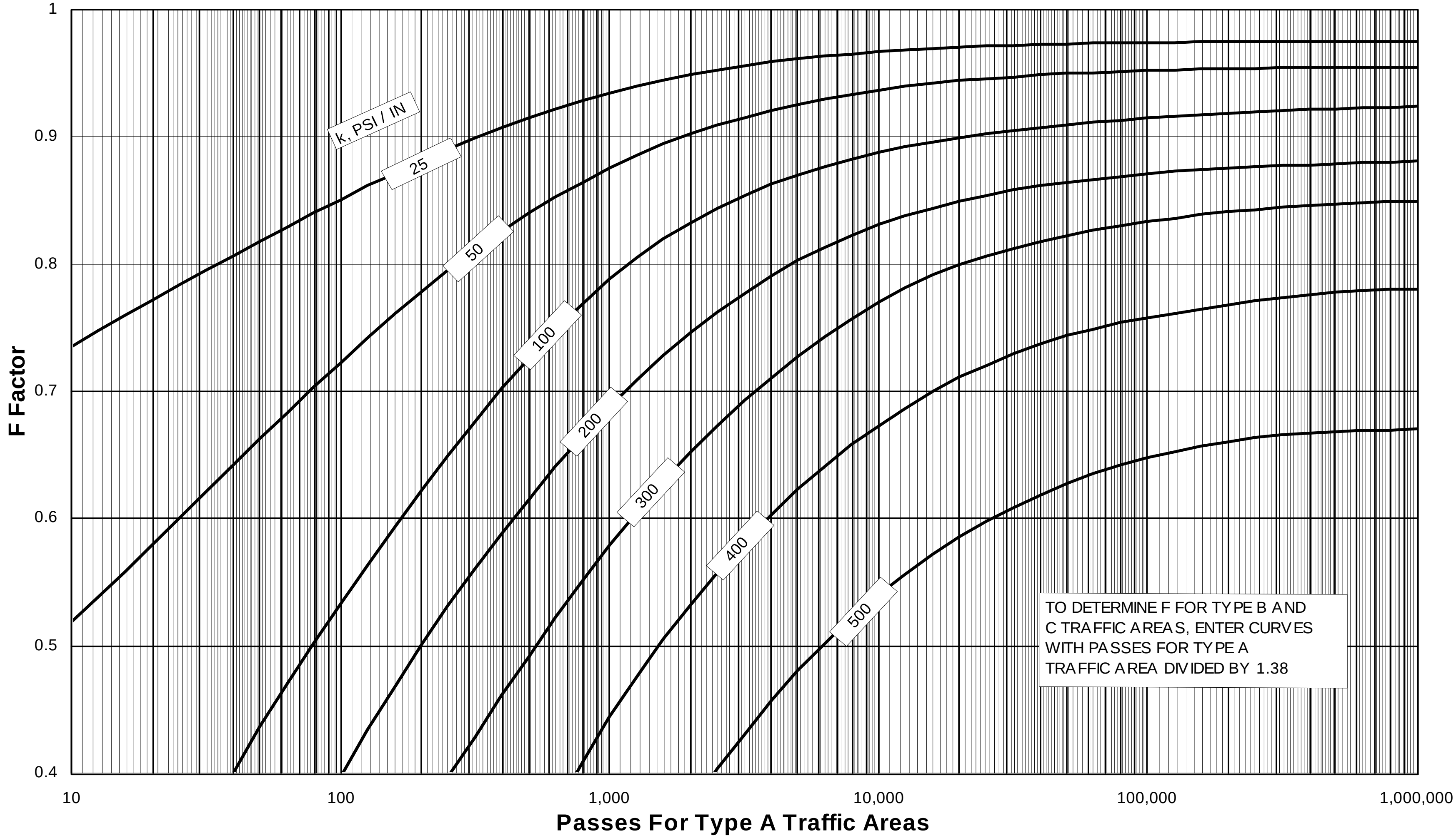
Appendix E: Nonrigid Equivalent Thickness Curves

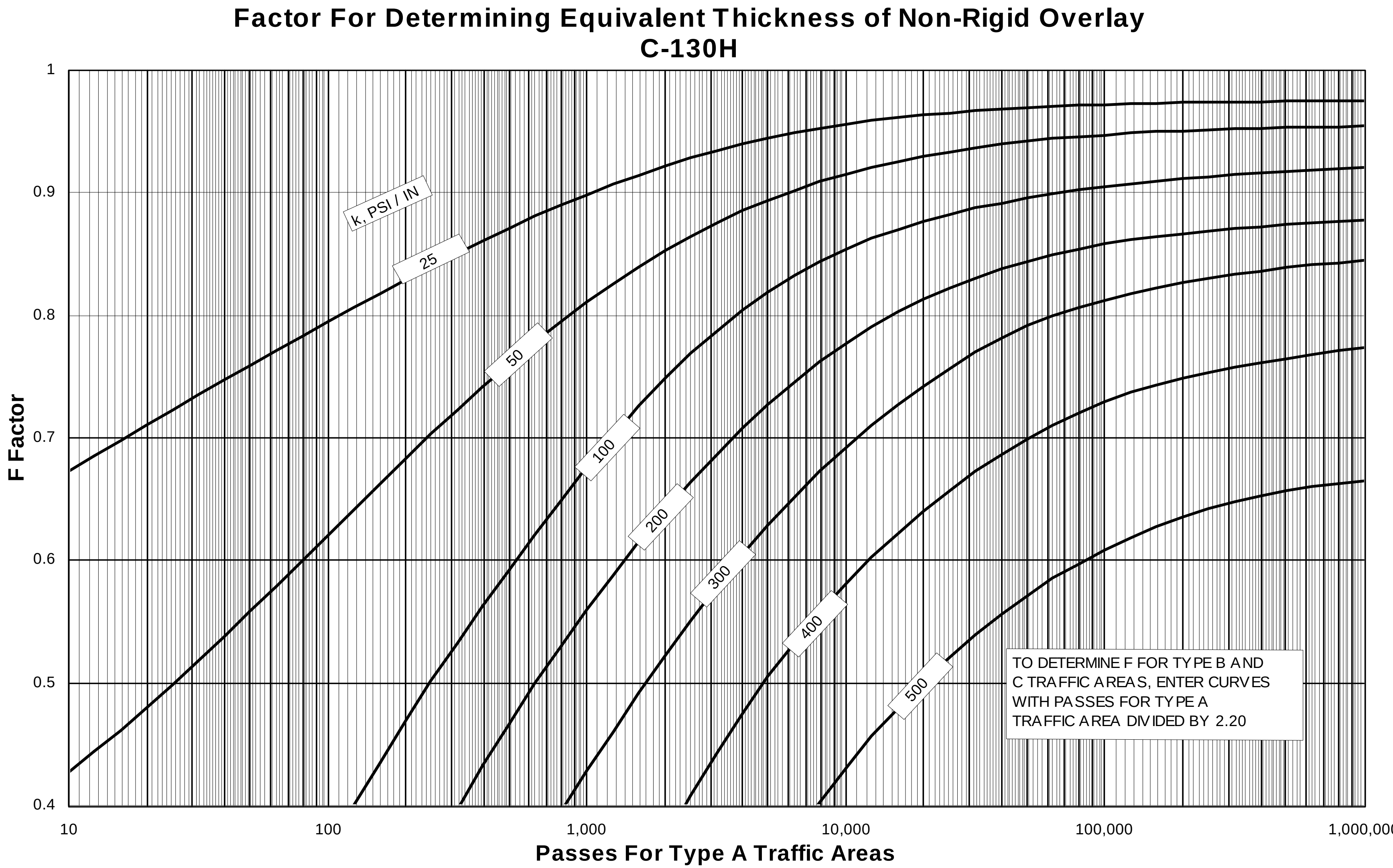


Factor For Determining Equivalent Thickness of Non-Rigid Overlay
C-5A

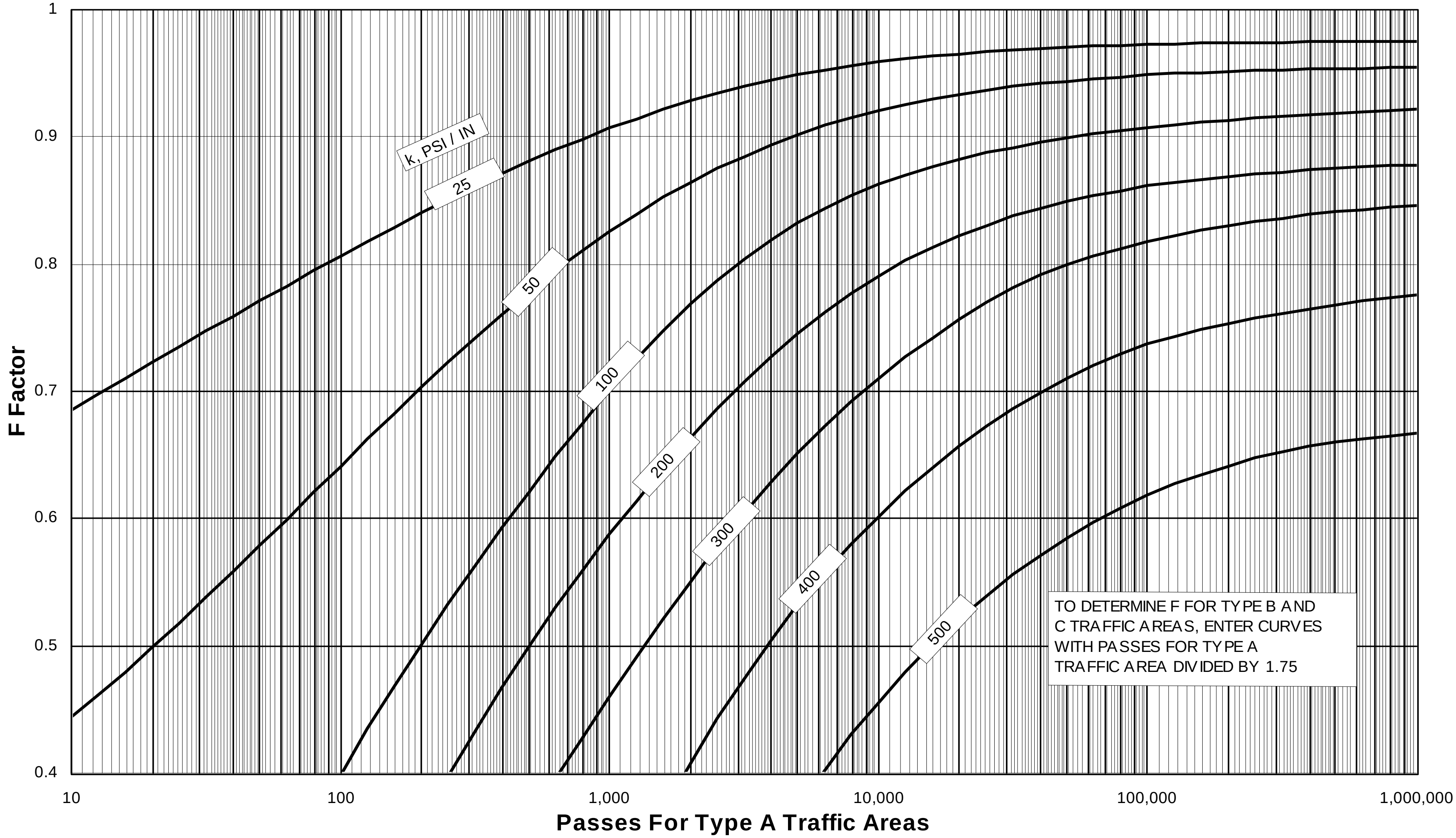


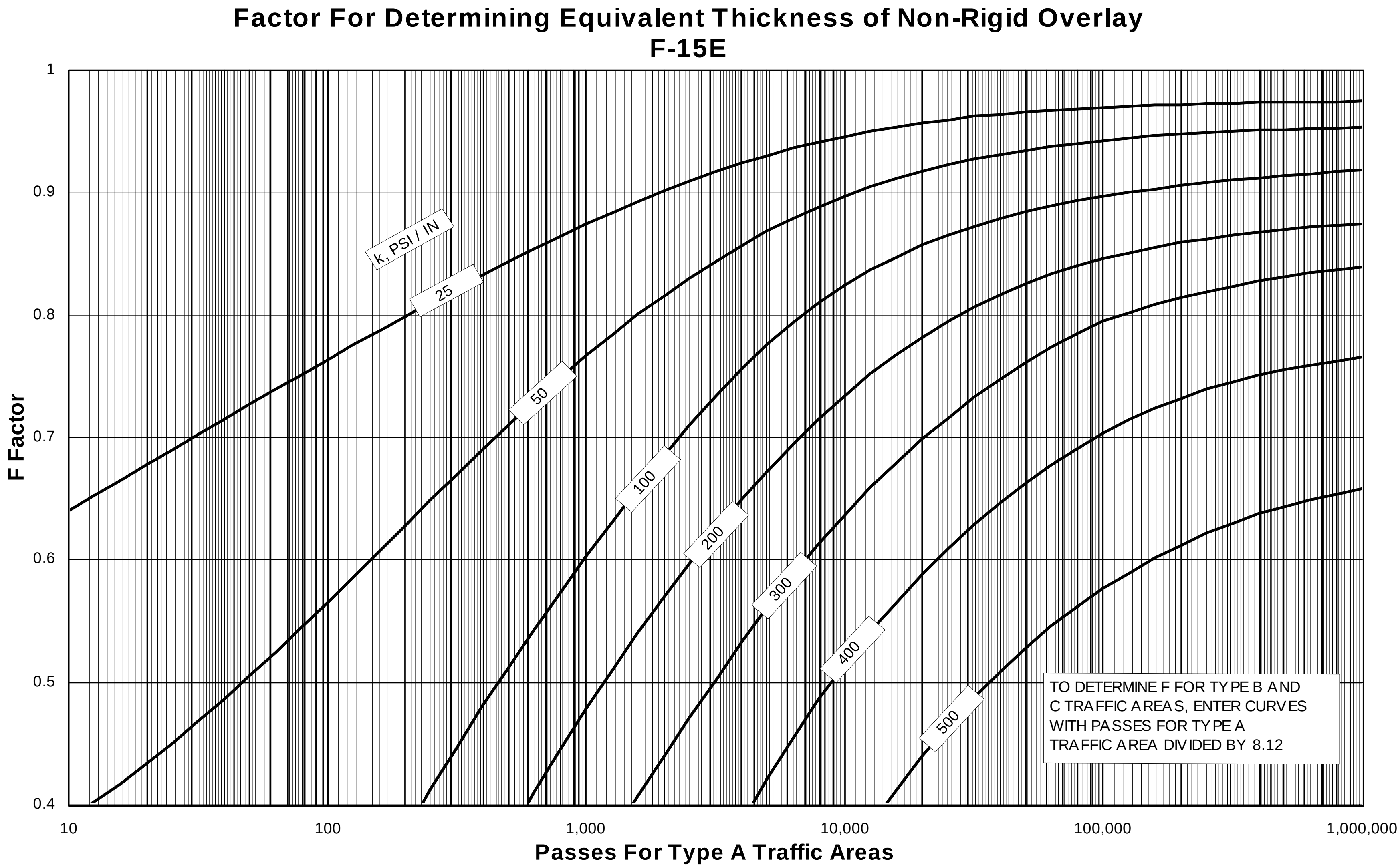
Factor For Determining Equivalent Thickness of Non-Rigid Overlay
C-17

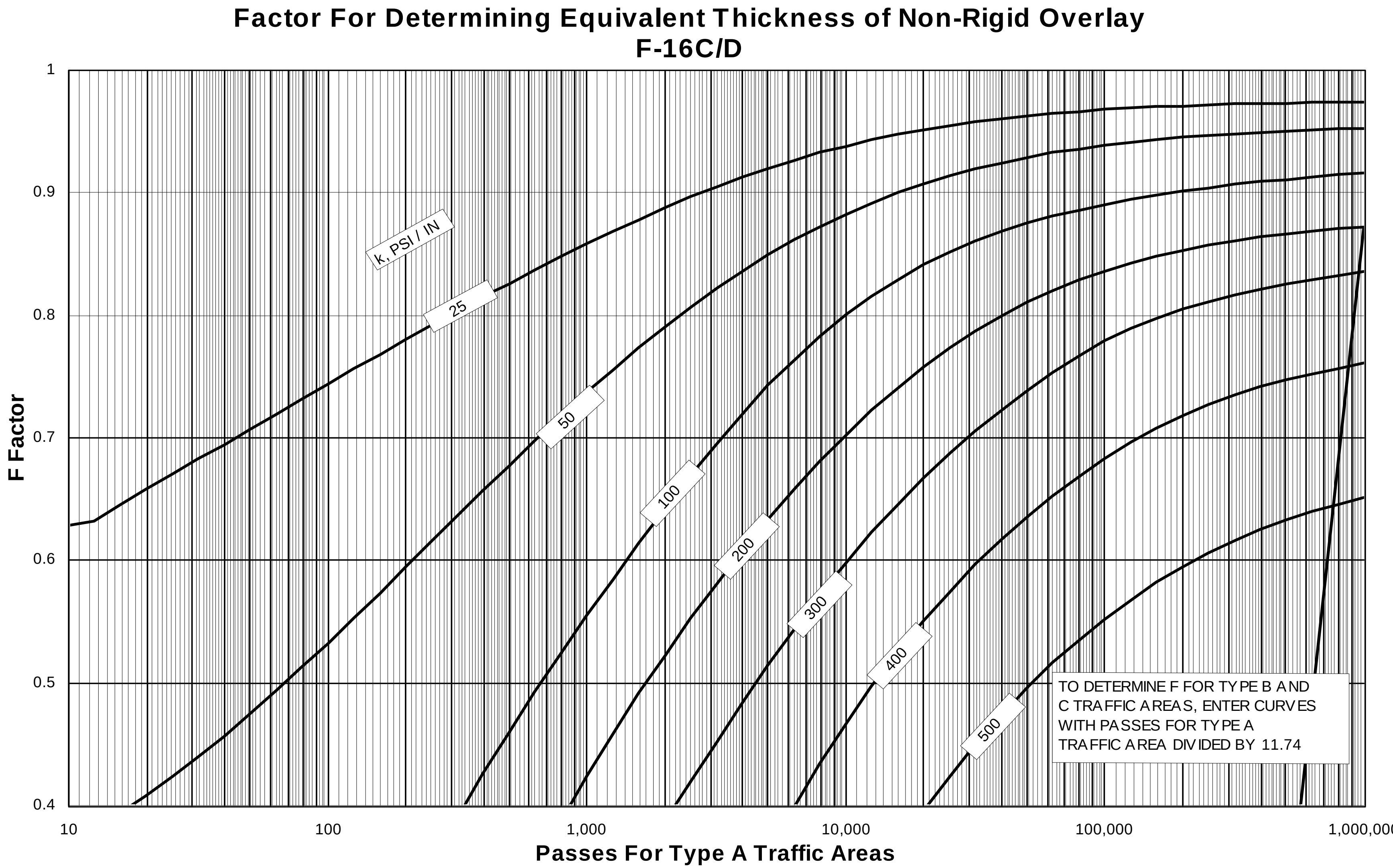


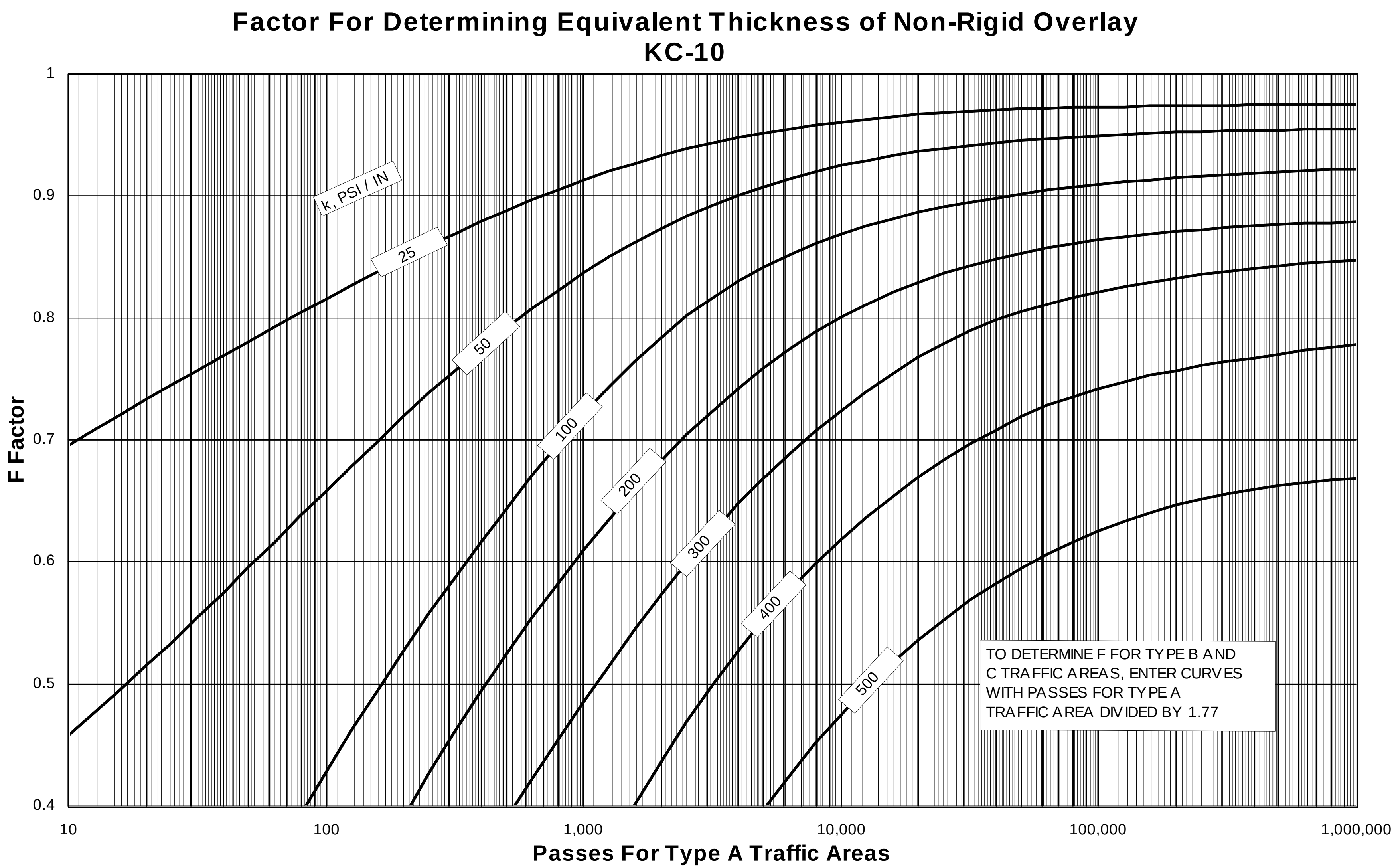

Factor For Determining Equivalent Thickness of Non-Rigid Overlay
C-130H
F Factor
Passes For Type A Traffic Areas
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
k, PSI / IN
25
50
100
200
300
400
500
TO DETERMINE F FOR TYPE B AND
C TRAFFIC AREAS, ENTER CURVES
WITH PASSES FOR TYPE A
TRAFFIC AREA DIVIDED BY 2.20

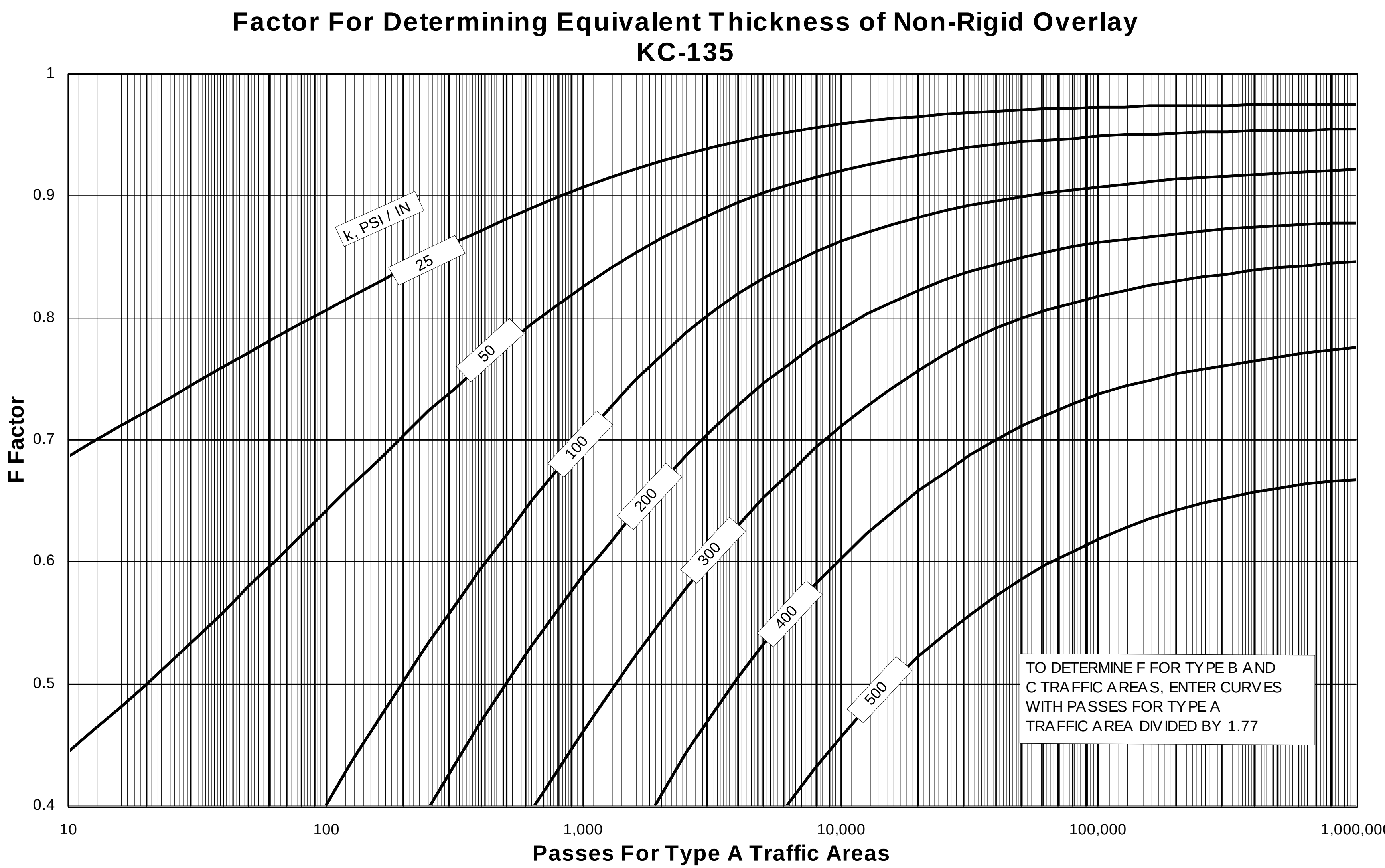
Factor For Determining Equivalent Thickness of Non-Rigid Overlay
C-141




Factor For Determining Equivalent Thickness of Non-Rigid Overlay
F-15E
F Factor
Passes For Type A Traffic Areas
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
k, PSI / IN
25
50
100
200
300
400
500
TO DETERMINE F FOR TYPE B AND
C TRAFFIC AREAS, ENTER CURVES
WITH PASSES FOR TYPE A
TRAFFIC AREA DIVIDED BY 8.12


Factor For Determining Equivalent Thickness of Non-Rigid Overlay
F-16C/D
F Factor
Passes For Type A Traffic Areas
k, PSI / IN
25
50
100
200
300
400
500
TO DETERMINE F FOR TYPE B AND C TRAFFIC AREAS, ENTER CURVES WITH PASSES FOR TYPE A TRAFFIC AREA DIVIDED BY 11.74
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000


Factor For Determining Equivalent Thickness of Non-Rigid Overlay
KC-10
F Factor
Passes For Type A Traffic Areas
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000
k, PSI / IN
25
50
100
200
300
400
500
TO DETERMINE F FOR TYPE B AND C TRAFFIC AREAS, ENTER CURVES WITH PASSES FOR TYPE A TRAFFIC AREA DIVIDED BY 1.77


Factor For Determining Equivalent Thickness of Non-Rigid Overlay
KC-135
F Factor
Passes For Type A Traffic Areas
k, PSI / IN
25
50
100
200
300
400
500
TO DETERMINE F FOR TYPE B AND C TRAFFIC AREAS, ENTER CURVES WITH PASSES FOR TYPE A TRAFFIC AREA DIVIDED BY 1.77
1
0.9
0.8
0.7
0.6
0.5
0.4
10
100
1,000
10,000
100,000
1,000,000

Appendix F: ACN/PCN Charts

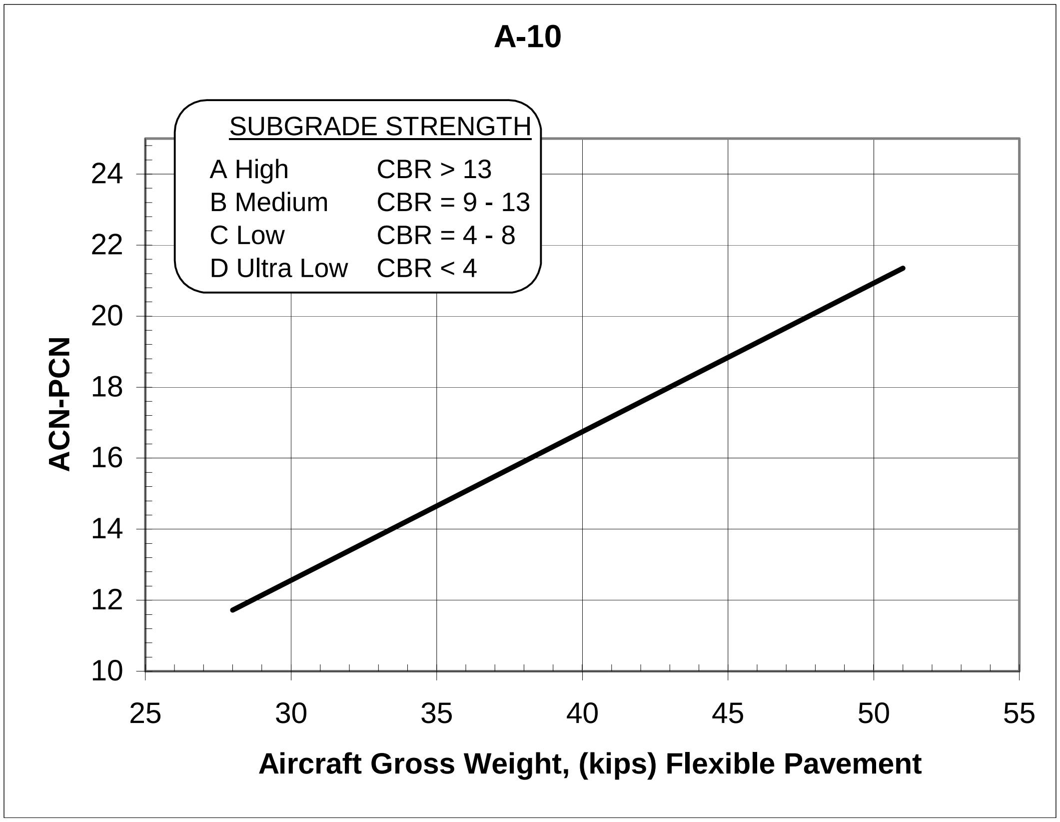
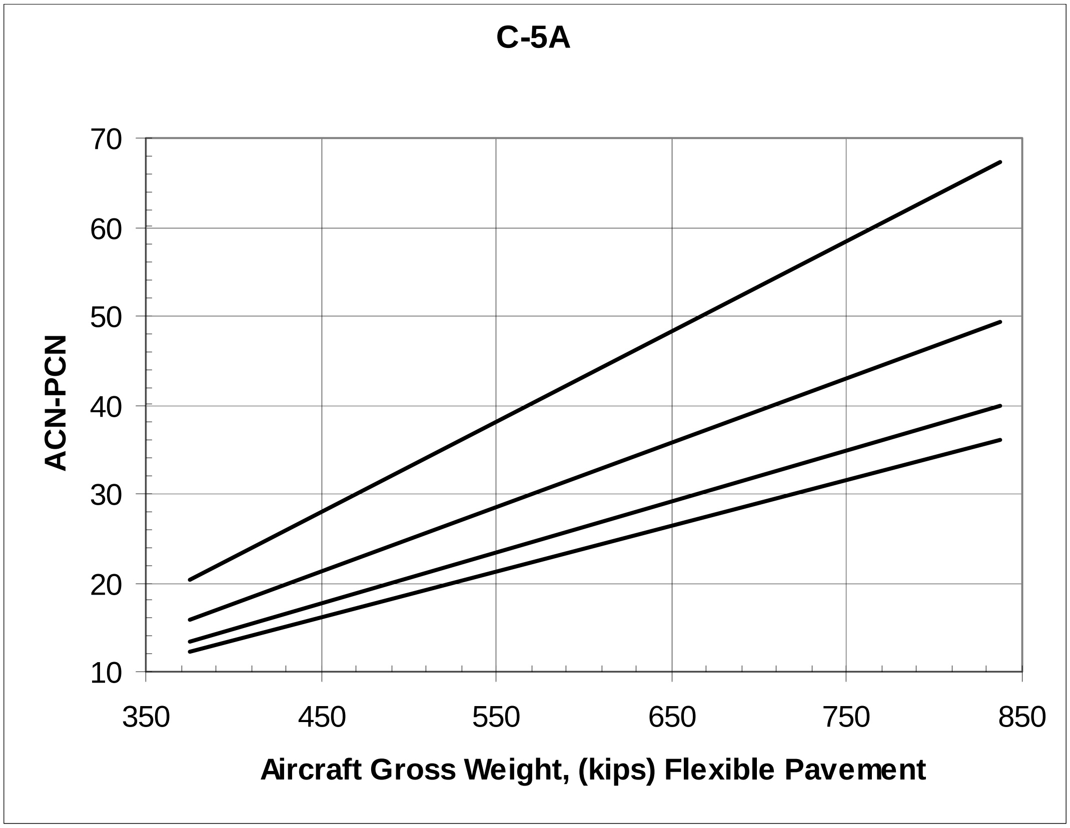


Figure F-1. ACN/PCN Curves for A-10



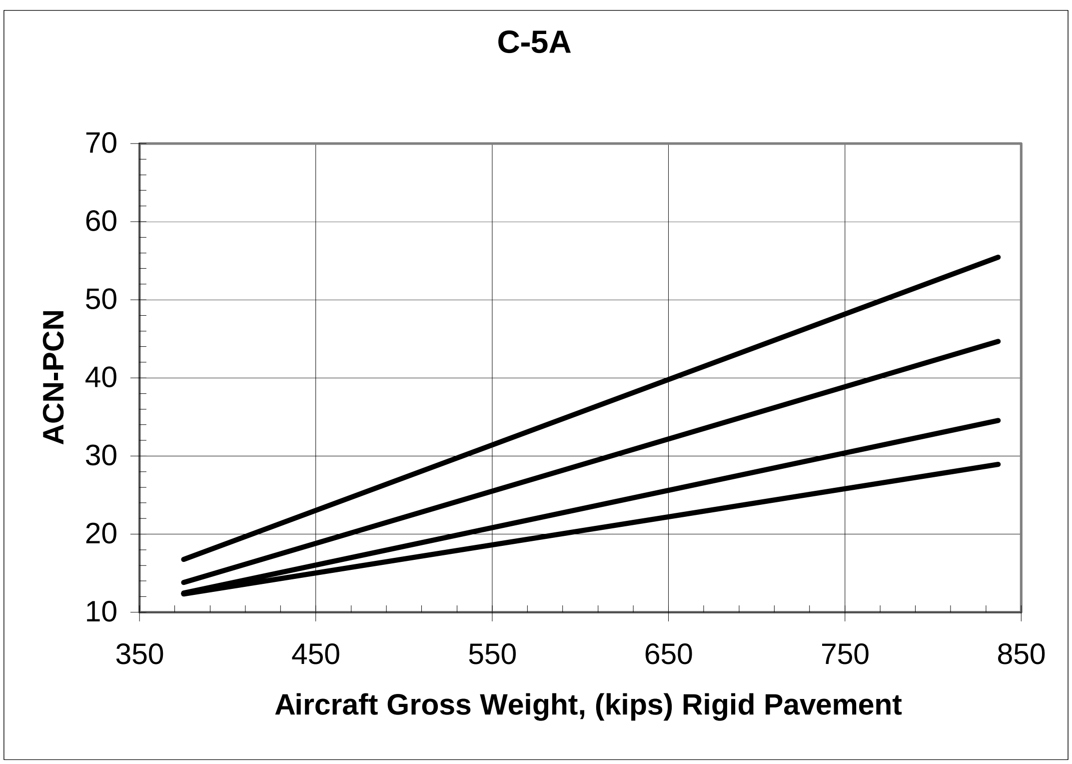
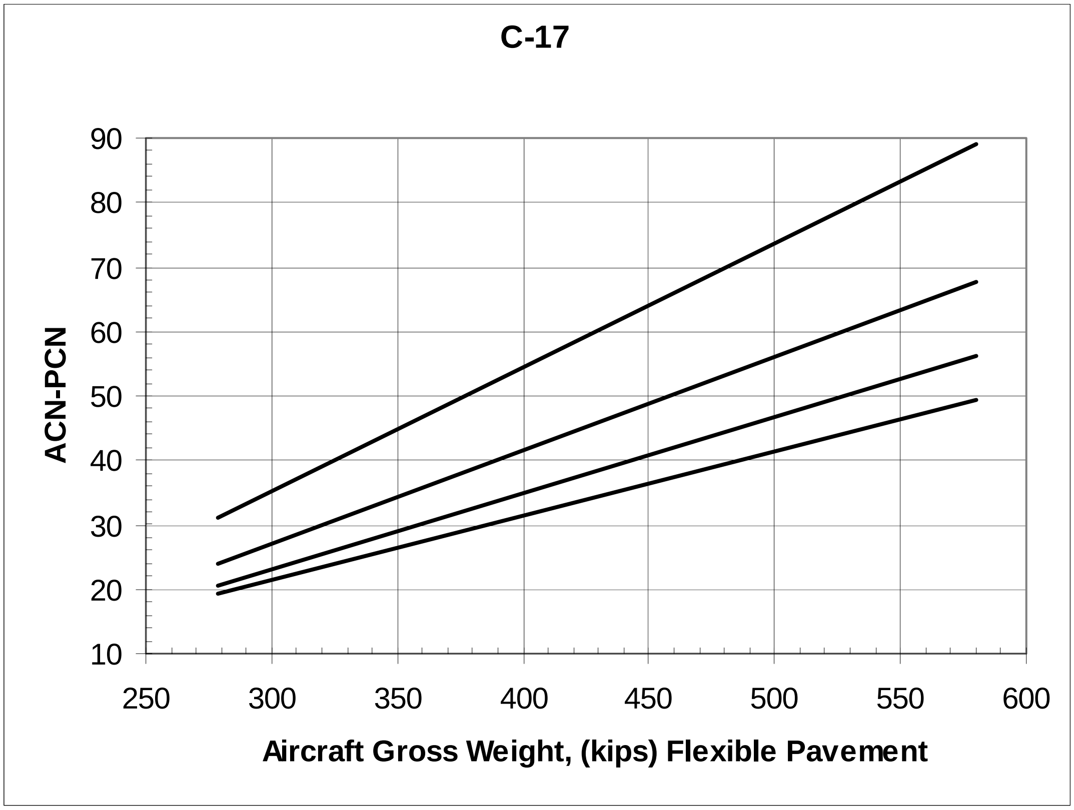


Figure F-2. ACN/PCN Curves for C-5A



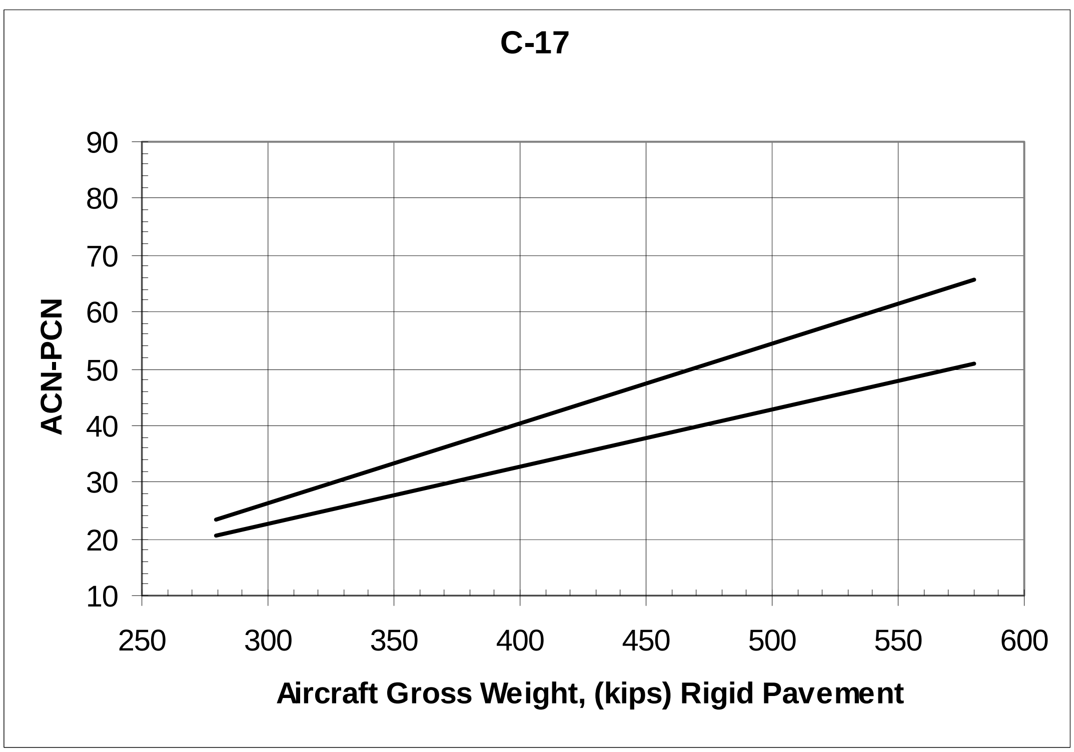
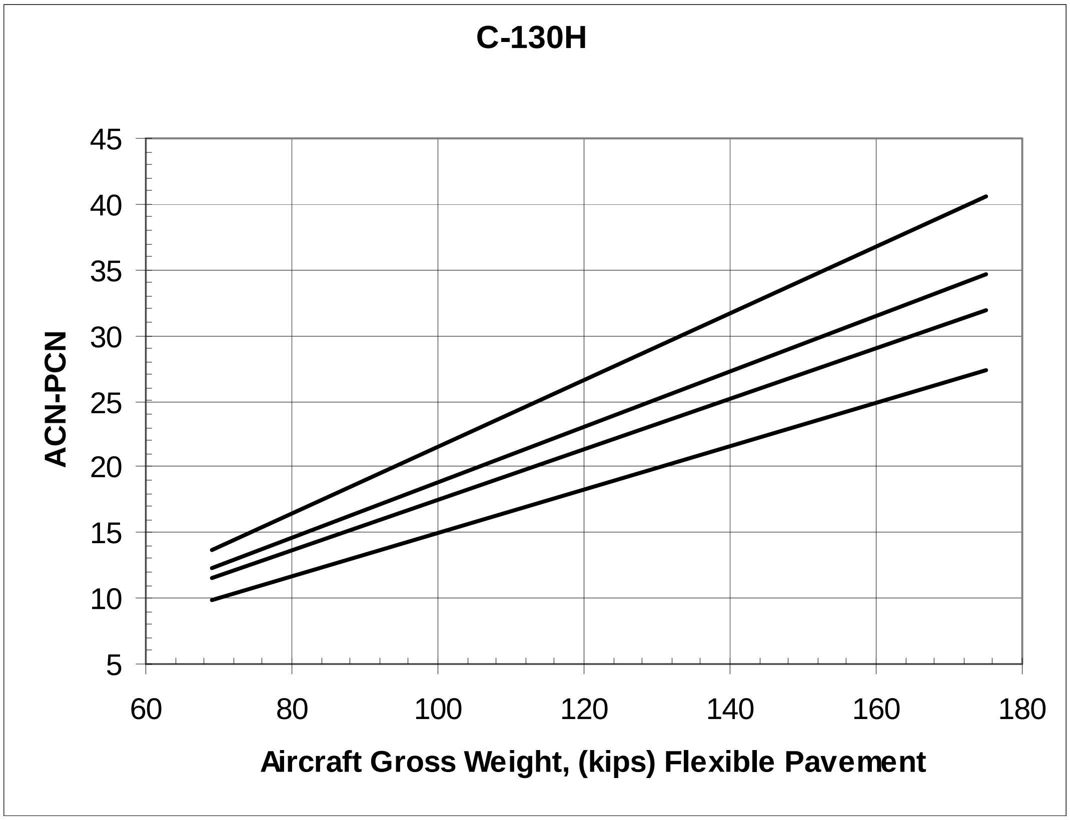


Figure F-3. ACN/PCN Curves for C-17



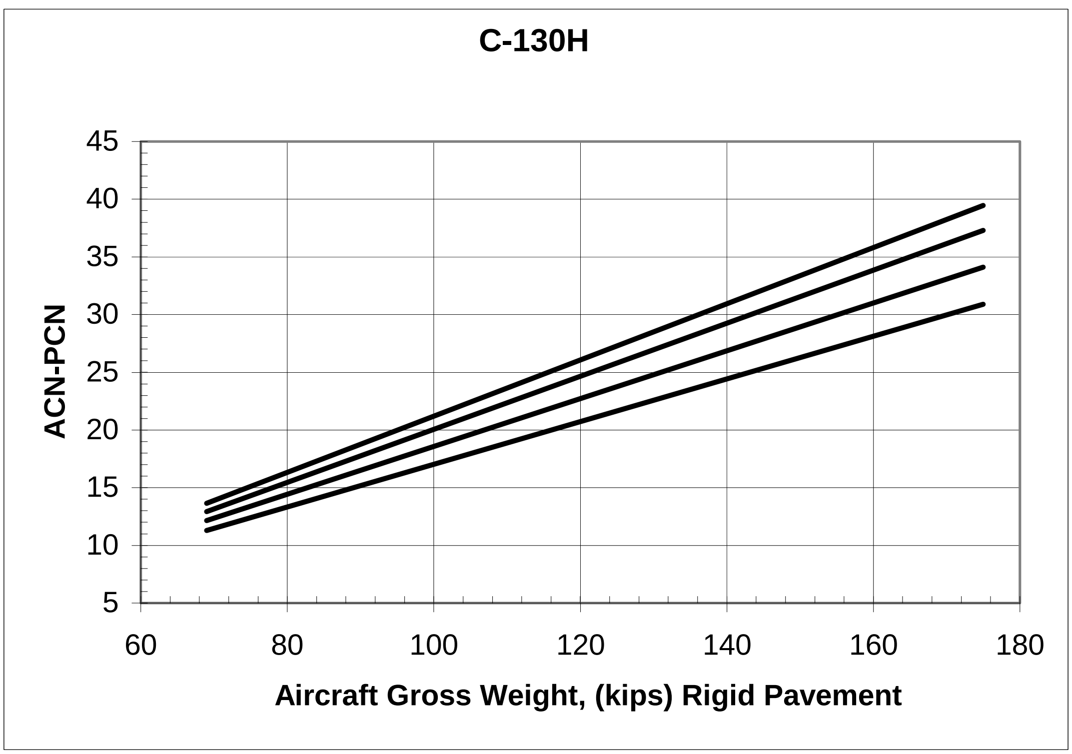
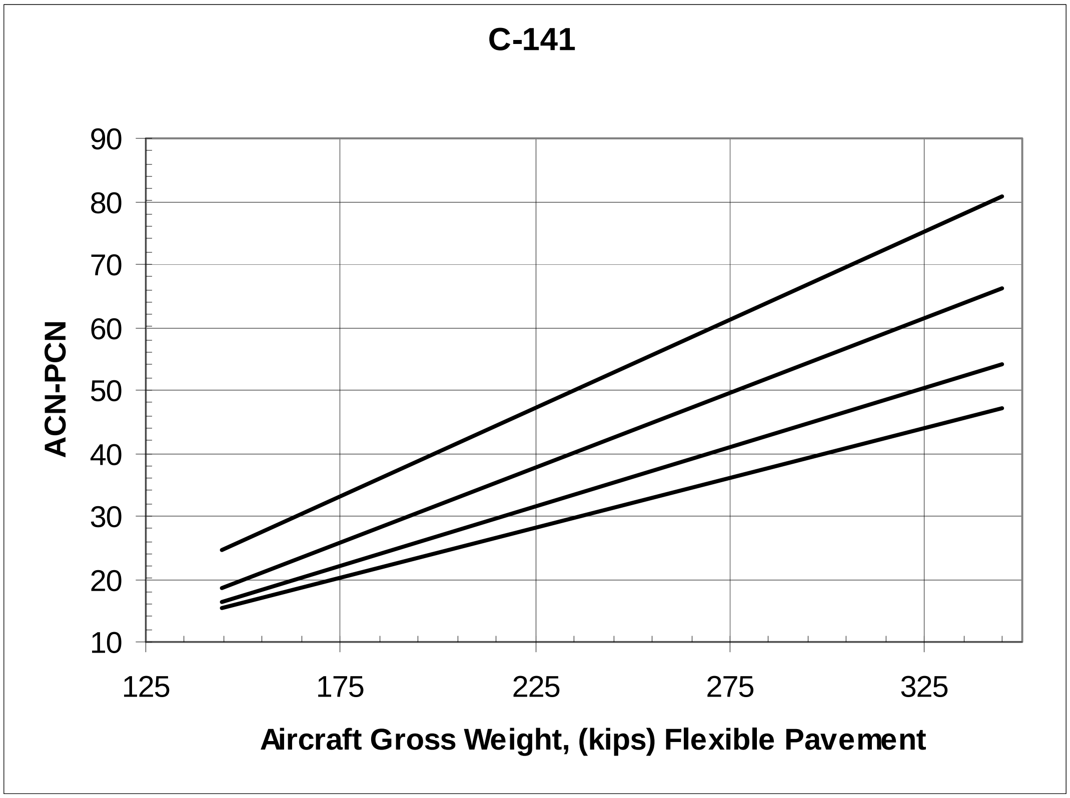


Figure F-4. ACN/PCN Curves for C-130H



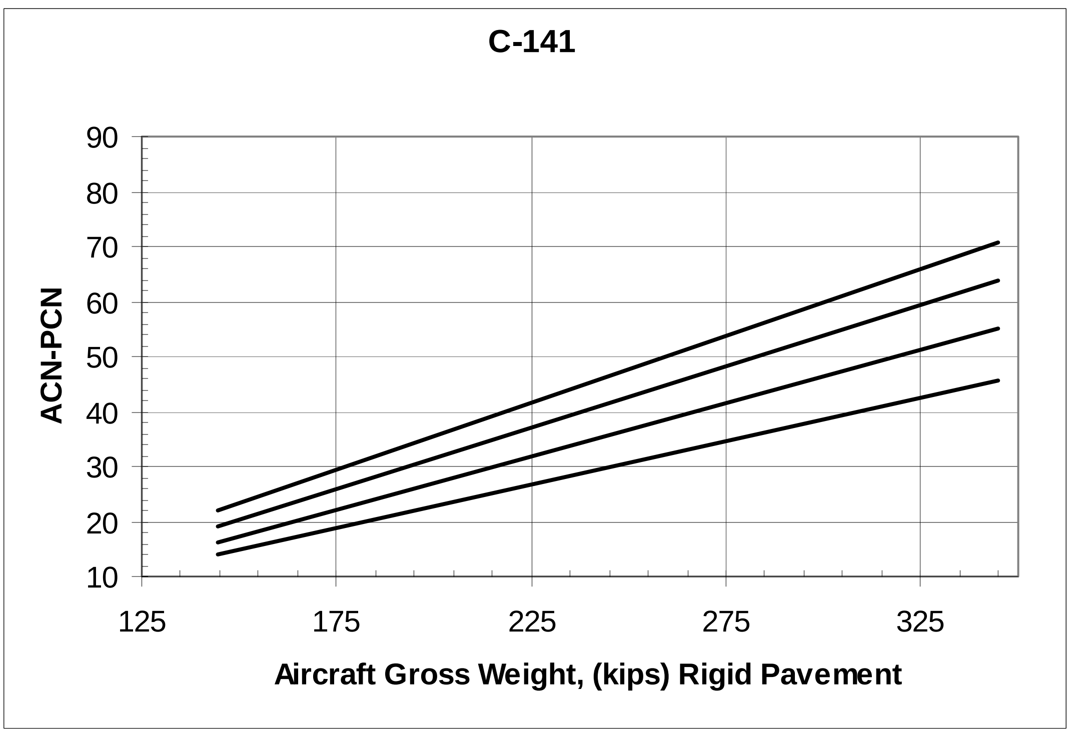
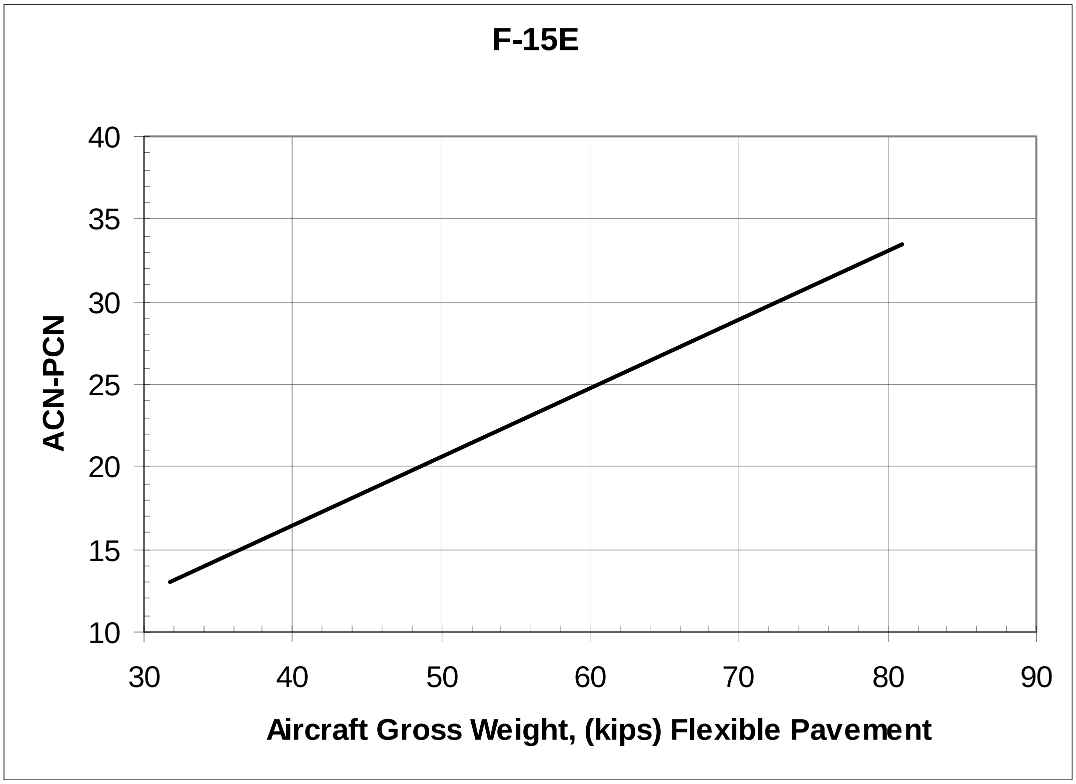


Figure F-5. ACN/PCN Curves for C-141



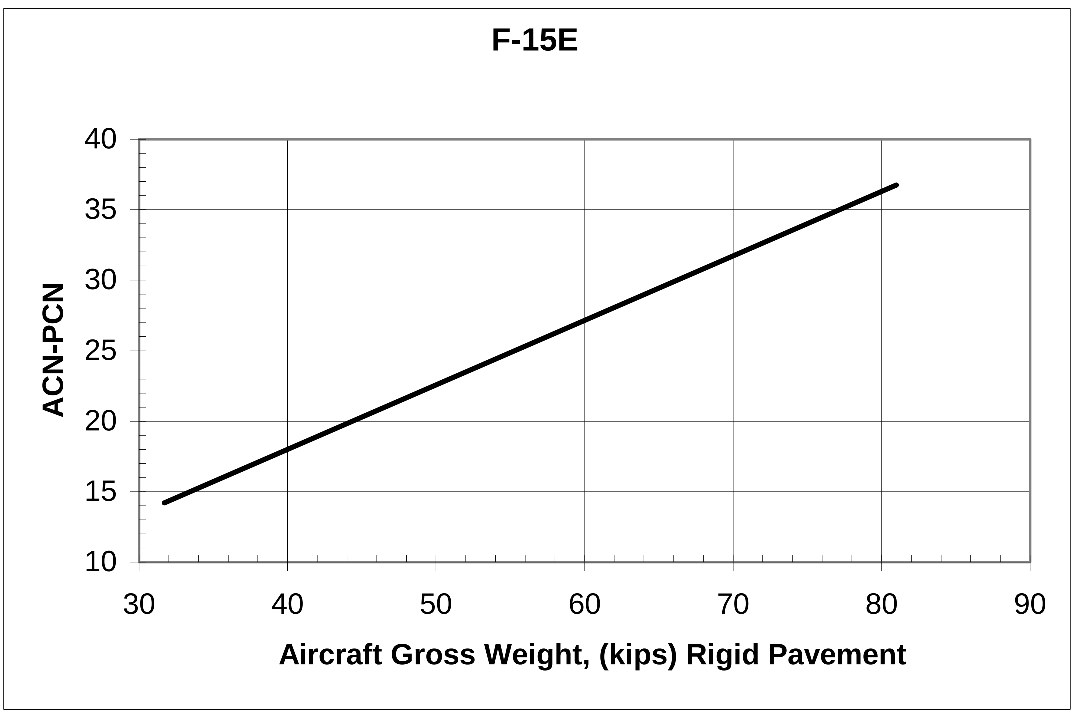
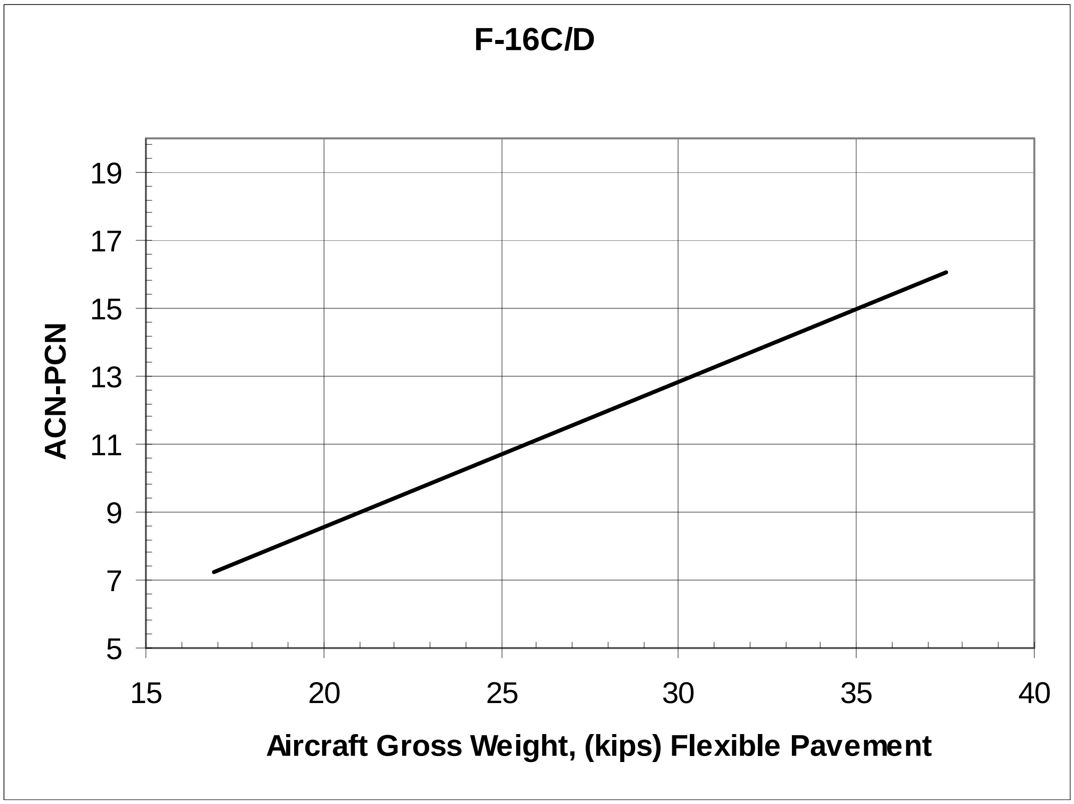


Figure F-6. ACN/PCN Curves for F-15E



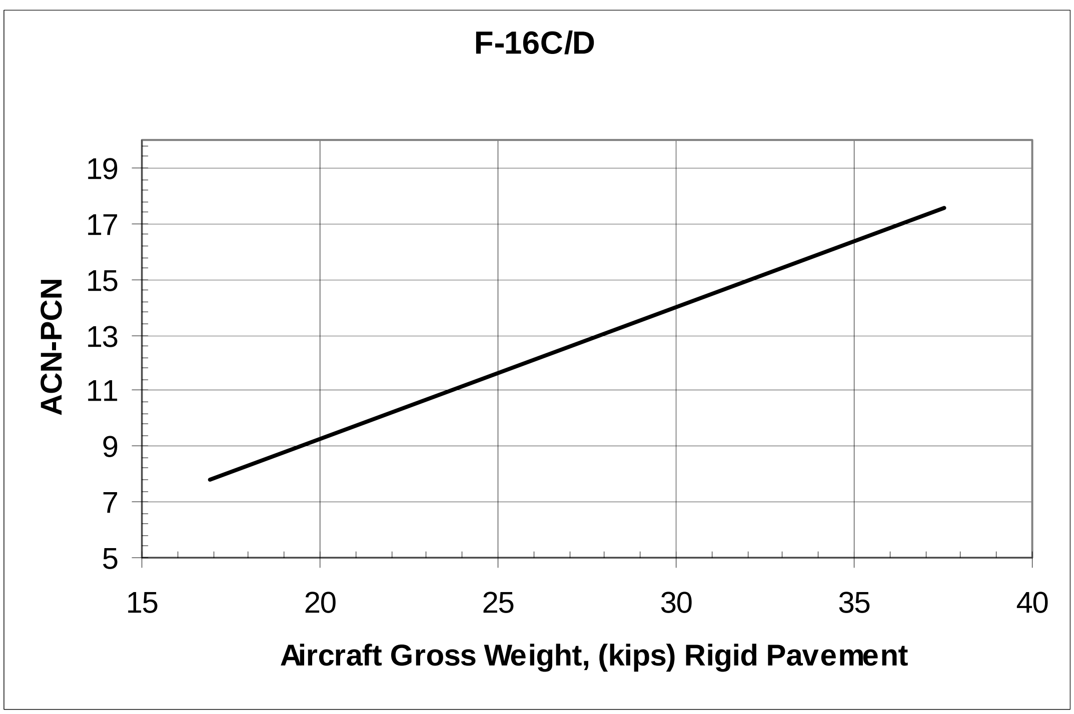
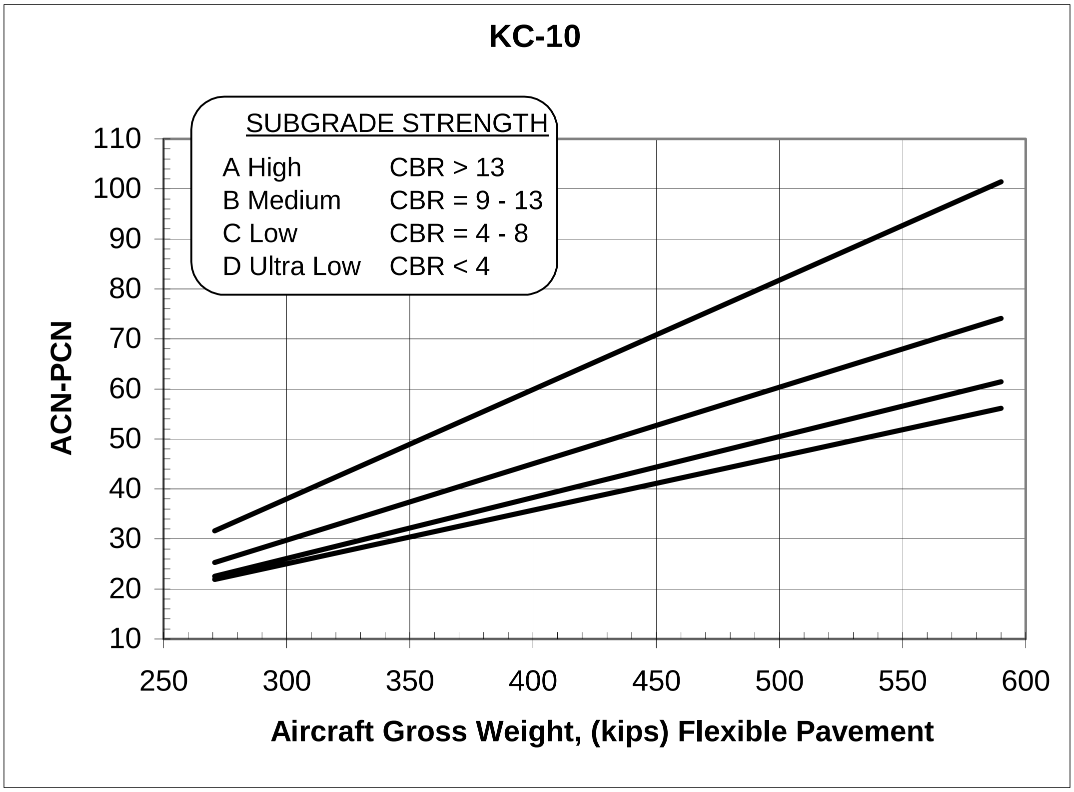


Figure F-7. ACN/PCN Curves for F-16C/D



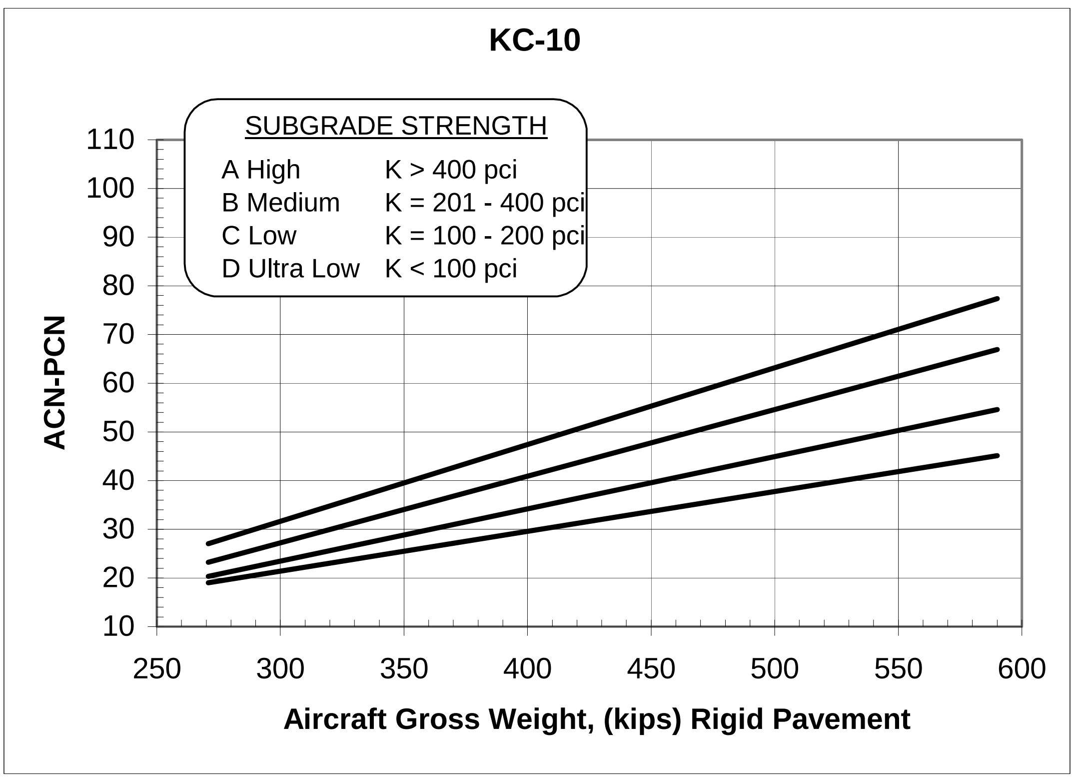
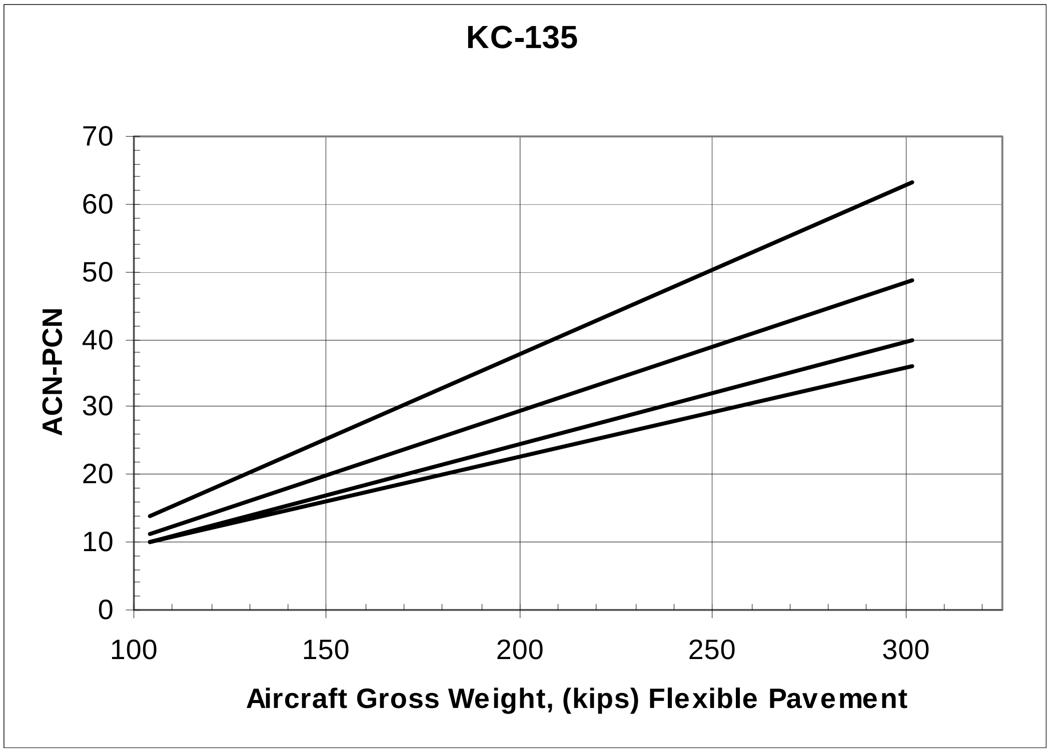


Figure F-8. ACN/PCN Curves for KC-10



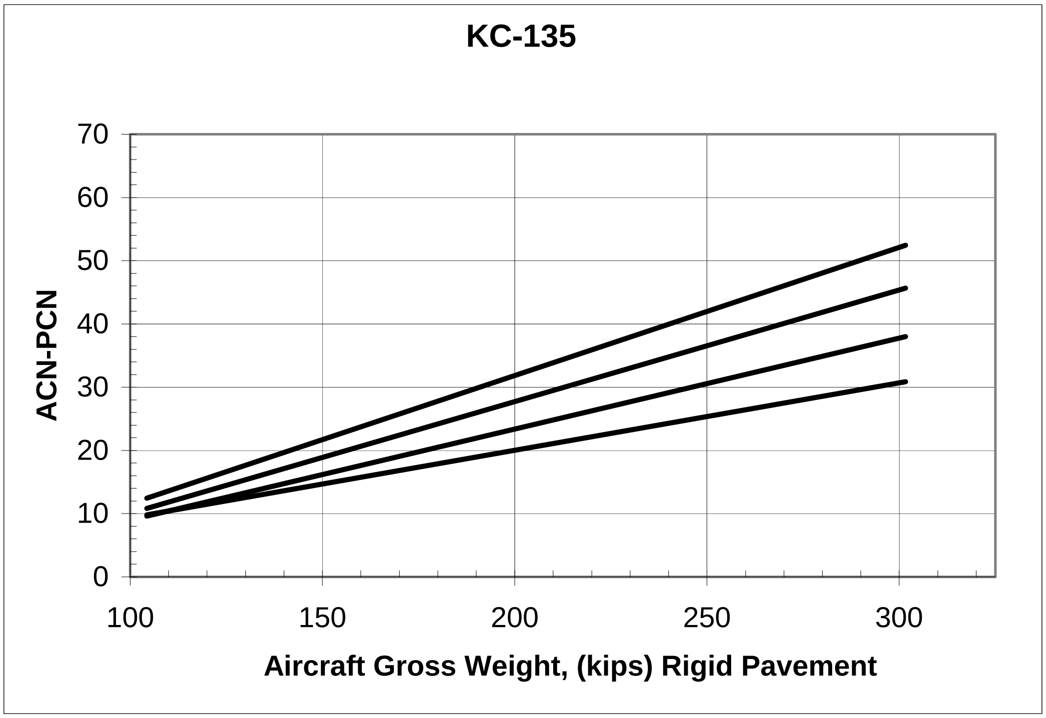


Figure F-9. ACN/PCN Curves for KC-135

Appendix G: Example Expedient Evaluation Report

ROSECRANS MEMORIAL AIRPORT, MISSOURI
AIRFIELD PAVEMENT SUMMARY
11 JUNE 2002

SUMMARY

At the request of MOANG 139th Airlift Wing, members from the 22nd CES/CEOE conducted an expedient airfield pavement evaluation at Rosecrans Memorial Airport, Missouri, on 11 June 2002. The purpose of the evaluation was to determine the structural capacity of the airfield. Available reports and data consisted of a 1996 ANGRC Pavement Condition Survey and as-builts of the runways. Dynamic Cone Penetrometer (DCP) tests were conducted throughout the airfield. These test locations are shown on the airfield layout included in this report. DCP test results along with other referenced data were used to calculate the Allowable Passes or Allowable Gross Loads (AGLs) and Pavement Classification Numbers (PCNs) in this report.

The reported PCNs for the airfield are as follows:

Feature	Published PCN*	Adjusted PCN**	Allowable Passes (# of passes at maximum weight before 100% of the pavement design life is used)				
			C-17	C-5	C-141	C-130	E-3
RW 1735		49 R/B/W/T	46,579	no limit	22,950	no limit	no limit
RW 1331		39 R/C/W/T	1,524	3,397	940	no limit	1,993
TW A & NE Ramp		46 R/B/W/T	11,652	49,530	7,535	no limit	18,750
TW B West		46 R/B/W/T	18,256	no limit	14,856	no limit	36,723
MOANG Ramp		49 R/B/W/T	41,484	no limit	45,454	no limit	no limit

* No published PCNs available for this airfield.
** Based on the AF standard of 50,000 passes of a C-17, weighing 585,000 lbs

C-17 allowable passes will increase significantly if aircraft weights are reduced to normal operating loads. For example, allowable passes for 525,000 lb C-17's would be unlimited for Runway 1735, Taxiway B East and the MOANG ramp, 48,367 for Taxiway A and 5,143 for RW 1331. A section of Runway 1735's outer edges (about 1-1/2 slab width) has a thinner pavement section with less capacity and should be identified should turnarounds or full width operations be required. Runway 13/31 is the weakest section of the active airfield and it should be closely monitored for accelerated deterioration as aircraft operations proceed. The General Aviation Ramp was not evaluated.

OBSERVATIONS

Overall condition of the active airfield appeared good with some minor spalling, joint sealant failure and asphalt weathering. However, a section of Taxiway A south end had moderate D-cracking. This area will require repairs to avoid becoming a future FOD hazard. Abandoned Runway 0422 & the Southwest Ramp/Hardstand were not evaluated but future plans may require their use as a hot cargo area. These abandoned pavements were in fair condition with moderate spalling, severe joint sealant failure and ponding at the ramp area - they will require pavement overlays to achieve required pavement capacity.

The entire airfield is in the Missouri River floodplain and drainage in certain areas needs improvement. Appears original construction from 1939 to 1943 generally consisted of 7 inch Portland Cement Concrete (PCC) pavement on existing subgrade for diagonal runways and taxiways and 13 inch PCC pavement on 4 inch base for Runway 1735 and Taxiway A and B. Runway 1735 and Taxiway A have been extended north about 2,000 feet as evident by raised grade, better drainage and better base/subgrade strengths. All active runways and taxiways were overlaid in the early 70's and 90's. The entire MOANG ramp is currently being reconstructed and expanded with 12 inch PCC pavement, 8 inch stabilized drainage course and 9 inch stabilized subbase.

Corner Spall, Runway 13/31

D-Cracking on Taxiway A

Poor Joint Seal, SW Ramp

Settlement and Ponding, SW Ramp

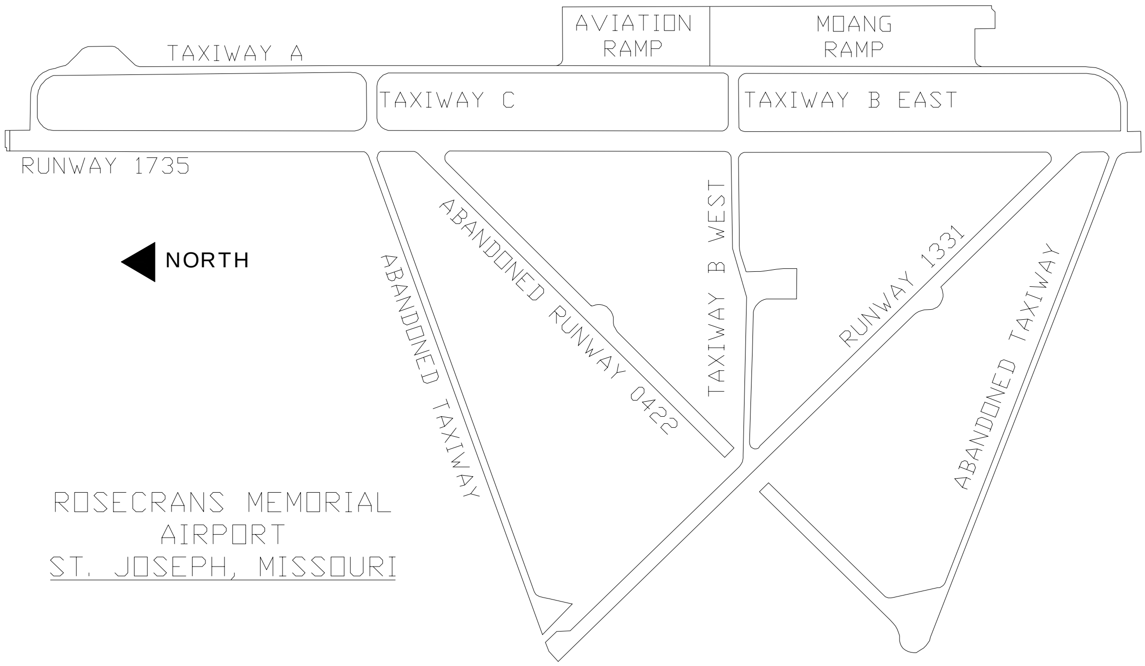
ANALYSIS

DCP tests showed a fairly consistent subgrade K value of approximately 200. Since DCP tests were not performed on the MOANG ramp, PCNs were calculated using verified construction sections, 650 psi concrete flexural strength and an assumed subgrade K value of 200. Extended life criteria was used for all PCNs calculated. The following are the controlling pavement profiles used for calculating the PCNs (profiles were determined by drilling and DCP testing).

SUMMARY of PHYSICAL PROPERTY DATA												
FACILTY					PAVEMENT			BASE COURSE			SUBGRADE	
Feature	Ident	Length (ft)	Width (ft)	Cond	Thick (in)	Descrip	Flex (psi)	Thick (in)	Descrip	K or CBR	Descrip	K or CBR
	RW 17/35			Good	7 13	PCC PCC	650 700				Silty Sand	250
	RW 13/31			Good	10 7	AC PCC	 700				Silty Sand	175
	Txy A & NE Ramp			Fair	7 13	PCC PCC	650 700				Silty Sand	200
	Txy B West			Good	7 13	PCC PCC	650 700				Silty Sand	200
	MOANG Ramp			Good	12	PCC	*650				*Silty Sand	*200

* Assumed from construction as-builts.

AIRFIELD LAYOUT



If more information is required or if there are any questions, contact one of the following evaluation teams:

22 CES/CEOE	HQ AMC/CEX	22 CES/CEC
(316) 759-5724	**(618) 229-0753**	**(316) 759-6874**

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